Instruments

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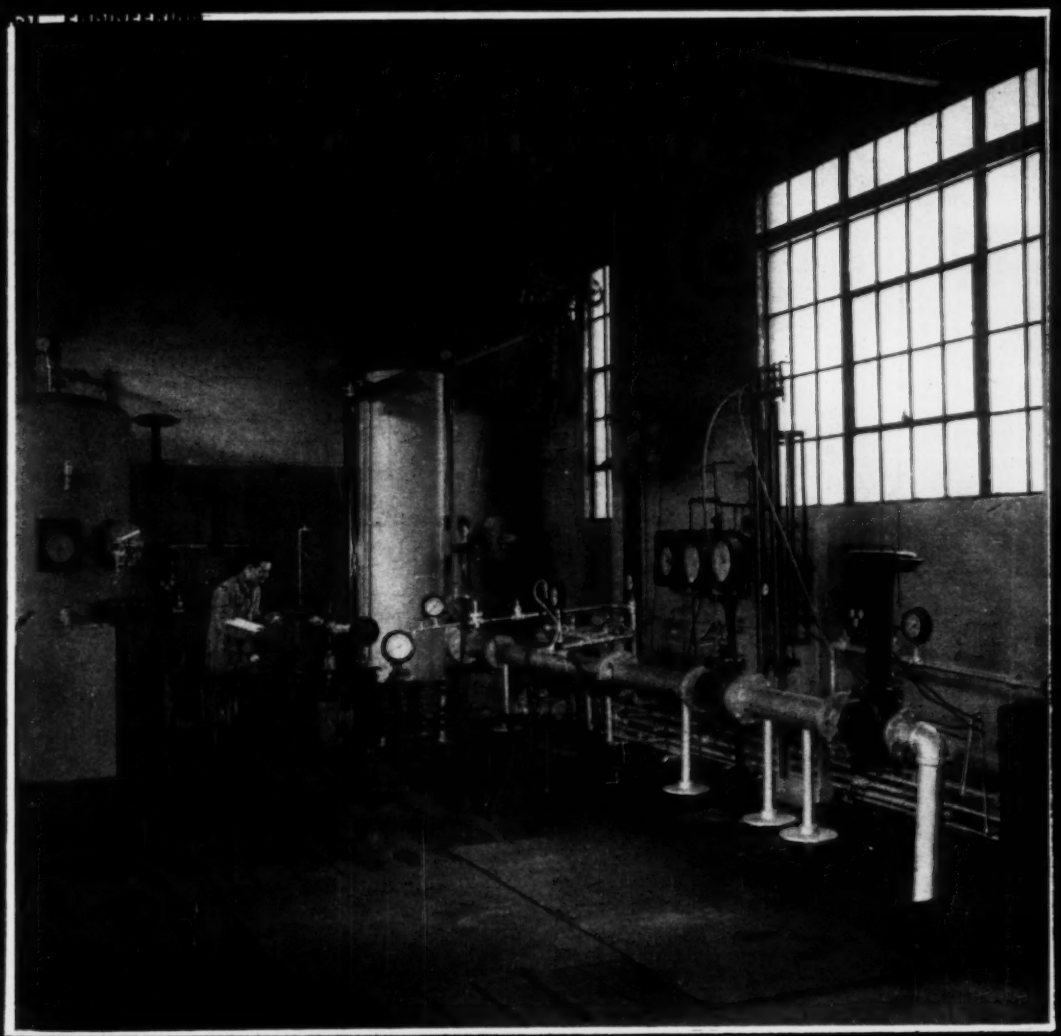

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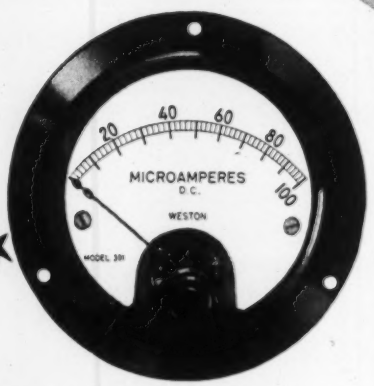

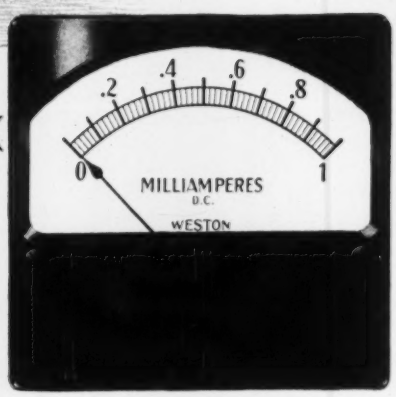

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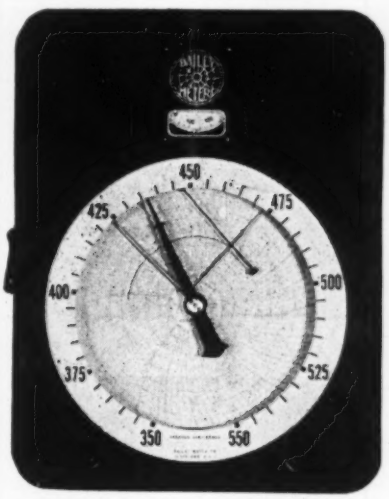

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EDITORIAL

By M. F. BEHAR

(1)

Cybernetics or Control and Communication in the Animal and the Machine. By Norbert Wiener. The Technology Press, M.I.T., Cambridge, Mass.; and Hermann et Cie, Paris; and John Wiley & Sons, Inc., New York 16, N. Y., 1948. Cloth, 6 x 9 inches, 194 pages. Price $3.00.

(2)

The Extrapolation, Interpolation, and Smoothing of Stationary Time Series, With Engineering Applications. By Norbert Wiener. The Technology Press, M.I.T., Cambridge, Mass.; and John Wiley & Sons, Inc., New York 16, N. Y., 1949. Cloth, 6 x 9 inches, 164 pages. Price $4.00.

OF THESE two books by the eminent Professor of Mathematics at M.I.T., the second is currently being reviewed in periodicals reaching less than a tenth of one percent of this country's population. The first got nation-wide publicity in late '48 and early '49. It's all wrong! The SECOND book is the momentous disclosure which the first book was incorrectly claimed to be. The second book really rates the first review—particularly on THIS page serving instrument users, because it will exert a powerful influence on the future of certain types of automatic controllers. This future influence, however, has to do with the old familiar concept of a controller as a brain. This concept is not exploited in the second book, but it is brilliantly exploited in the first book. Therefore the two books will be reviewed in the order of their appearance.

(1)

The first-issued book of this ill-assorted pair got so much publicity that some of our subscribers must wonder why we've waited so long to review it. Two reasons:

First, the American publishers (book set up in France) didn't send a copy to *Instruments The Magazine of Measurement AND CONTROL* until weeks after sending a review copy of the second, and only when we dropped them a postal card asking why.

Second, the blatant publicity, in class-media as well as in mass-media, sang the same refrain over and over: that a great genius had suddenly created a new science, the science of Automatic Control, whereby robots could for the first time be designed and built to perform nearly all of man's work and much of man's thinking (and so on . . . remember?). So we reacted the same way as did many other old-experienced "gadgeteers" and "plumbers": we didn't even want to see the darn book! At that time, we told an equally indignant friend that if we did get a review copy we would use the famous words of Dorothy Parker in *The New Yorker*: her review of a sexy novel (or play, or movie—it doesn't matter) was worded thus:

"I wanna frow up!"

That's what the high-pressure publicity mill did to one tech mag ed who admires and respects all competent scientists; who feels awe toward great mathematicians in particular; who had, since the nineteen-twenties, felt something like veneration toward Norbert Wiener after hearing about some episodes in the childhood, boyhood, adolescence and professional career of this mathematical prodigy.

That's what the well-oiled publicity machine did. Its impacts felt like a series of rabbit punches and kicks in the groin. We resented the blurbs ABOUT "cybernetics" more than we deplored the arrogance of coining a new word for what was an old science ON THE EVIDENCE OF THE SUBSTANCE OF THE BOOK-REVIEWS, NOT OF THE ADJECTIVES. At that time we weren't so sure that the author was arrogant: we half-believed half-wished that events would show that Wiener's only fall had been to fall for the persuasions of experts in the modern art of The Coast-to-Coast Build-up. When finally the mail brought a review copy, we first scrutinized the jacket blurb—for a jacket blurb is customarily written by the author. Here it is in full:

"A study of vital importance to psychologists, physiologists, electrical engineers, radio engineers, sociologists, philosophers, mathematicians, anthropologists, psychiatrists, and physicists. CYBERNETICS describes the application of statistical mechanics methods to communications engineering. Its subject matter ranges from such control mechanisms as servomechanisms, mathematical calculators, and automatic pilots, to the nerves and brain of the human body. This is a study of human control functions and mechanico-electrical systems designed to replace them. As such it impinges on every branch of science. It is the outgrowth of extensive theoretical study and experimentation by Dr. Wiener and a group of outstanding scientists—including physiologists, psychologists, mathematicians, and electrical engineers."

As should every conscientious reviewer, this one read the book from cover to cover. (No index between last textual page and back cover.)

Then we read many long passages a second time. Then we read a third time, and a fourth time, a few passages of varied lengths.

In spite of our respect for Wiener's mathematical genius, this toilsome study led us to conclude that except for hints of Wiener's great mathematical invention disclosed in his second book, there is nothing new in "Cybernetics." This is a free country. Anyone may coin any name, but the word "Cybernetics" is not only a superfluous neologism but, WITH THE PUBLICITY IT GOT, it is a harmful neologism. It is harmful to biophysicists, biochemists and biometrists; to sociologists and sociometrists; to psychologists and psychometrists; especially to many groups of workers in the physical sciences and technologies, including you and you and you. It has done harm because, aided and abetted by mighty publicity, it has concealed the fact that most of the book's subject-matter is old stuff and it has robbed the true pioneers of the credit they rightfully deserve. We haven't heard of one of them being fired and a Wiener man hired, but it might happen. The impression created by the publicity is so incorrect, so unjust, that we hope it will burst like a bubble. Unfortunately, this bubble has a thick skin by reason of the long-lasting effect of the great chorus of flattery in periodicals all issued within a few months—scientific journals as well as mass media—so that library researchers and historians for decades to come will gain the same hideously unjust impression. Yes, it will be difficult and unpopular to prick the sparkling bubble. This editorial review of two books will not do it.

By the way, this double-barrelled review will NOT be circulated artificially as is done by many periodicals. To "disclose" a widely-known secret; Many periodicals send advance proofs of contributed articles, of pictorials, of staff-written surveys, of editorials, etc., to *other* periodicals, to newspapers, to wire services, to radio news services, etc., in order to get free publicity; and they often get it because those on the receiving end expect to be on the sending end. "You scratch my back and I'll scratch yours." NEVER has *Instruments* engaged in this practice—though it is legal, legitimate and (when not abused) ethical. Therefore, no PREprints of this editorial are being ordered. REprints will be available if the extent of the demand justifies the expense.

Another aside: The word Instrumentation was adopted, at a dinner conference in January 1924, to designate the Science of Measurement AND Control which was to be formulated, but which had existed even before as an unwritten combination of sciences, technological know-hows, and other ingredients. (No new word was coined: "instrumentation" already existed as a word in musicology.) There was no publicity. A small society was formed, but later disbanded in favor of a planned Perpetual Project (which lives today in dispersed members like a banyan tree, see *Instruments*, Aug. 1942, page 300.) The first formulator of the new science did not even comply with suggestions that he notify the publishers of dictionaries that Instrumentation had a new, non-musical, potentially useful meaning. To this day, he has never communicated with any lexicographer. In 1931 a one-word name was sought for the aspect of the science of Instrumentation having to do with living organisms, animal societies and human societies, and their control. The suggestion, "kratology" or "cratology" (from the Greek root meaning "to exercise power") was rejected in favor of the older term "The Greater Instrumentation" and as such it was briefly defined in 1932 in the preface of an unsung book. Still no "build-up." Even in the early nineteen-forties, when newcomers jumped on top of the bandwagon and smiled into camera lenses, the obscure formulators (by that time there were several) kept off the bandwagon they had made possible.

Still another aside: The control branch of Instrumentation is sometimes called the science of "Automatics" or of "Automaticity" or of "Automatization."

Dr. Wiener's first book opens with a 32-page Introduction (68 percent longer than the average chapter length) explaining, mostly in charming narrative form, how the book came into being: It had its inception ten years before, in "discussion meetings on scientific methods" where "the conversation was lively and unrestrained." The author names many of his own co-workers without a trace of the condescension he displays toward other workers, in the Introduction and in several chapters. Throughout this Introduction he harps on the breaking of new ground—using the first person—when he is entitled to and (we suspect) when

priority is disputable. For example, on page 15:

"However, an excessive feed-back is likely to be as serious a handicap to organized activity as a defective feed-back. In view of this possibility, Mr. Bigelow and myself approached Dr. Rosenblueth with a very specific question. Is there any pathological condition in which the patient, in trying to perform some voluntary act like picking up a pencil, overshoots the mark, and goes into an uncontrollable oscillation? Dr. Rosenblueth immediately answered us that there is such a well-known condition, that it is called purpose tremor, and that it is often associated with injury to the cerebellum . . . most significant confirmation of OUR hypothesis . . . OUR point of view considerably transcended that current among neurophysiologists . . . a NEW step in the study of that part of neurophysiology which concerns not solely the elementary processes of nerves and synapses but the performance of the nervous system as an integrated whole."

[Some words capitalized for emphasis. No apology offered because none needed.]

This abridgement, and others to follow, may be challenged as unfair. All are fair because the omitted context, in every quotation, has no bearing on the validity of our comments. In this case we assert that this contribution to unified biological and physical sciences, or to any single "new" science, was trivial—even if it was new. Are we prejudiced? We think not—not now, not after fifteen months have healed the lacerations of the publicity campaign. And if the resentment aroused by those offensive proclamations of a "new" science has not quite died down, it is because of a multitude of memories of many old lectures, many old teachings, many old technical papers, many old achievements by many old acquaintances or associates—witnessed or participated in.

Pervading the whole book is Dr. Wiener's deliberate non-recognition, or mere unawareness, of his precursors' achievements in precisely this interscience field. It seems to us to be mere unawareness, although his sneer at Nicolas Rashevsky (page 58) indicates that Wiener does consider himself more competent in biophysics than this member of the team of great men who founded the sciences of biophysics and mathematical biology and have for twenty years displayed a penetrating insight into interscience problems.

Dr. Wiener, when writing this book, was evidently suffering from over-specialization. In the third paragraph of his introduction he asserts that for years he has been convinced that "the most fruitful areas for the growth of the sciences were those which had been neglected as a no-man's land between the various established fields." Throughout this book he boasts of cultivating this fruitful but neglected no-man's land with unprecedented success. (The foregoing quotation is but one of many passages full of "We did this and that for the first time.") But in this interscientific aim, the book is a dud because Wiener can't see the forest for the trees. To view the interscience areas ones needs a telescope: Wiener uses a microscope. The point of view that pervades his dissertations on muscular dynamics, brain-cell dynamics, social dynamics, etc., is fascinating—but narrow. It is the viewpoint of the transmission specialist. This of course is Wiener's glorious accomplishment—his *second* book—but even Wiener's most ecstatic admirers must admit that the narrowness of this viewpoint, in this first book, becomes tiresome. In this book Wiener is not a methodologist—which the formulator of a science must be above all else. He is a metrist—brilliant, outstanding, incomparable today and perhaps for centuries to come, but a metrist—a narrow specialist. Less-gifted men, in the last hundred years, have produced more stimulating and more profound interscience essays.

Being a metrist and not a methodologist in fields outside his ken, but being unaware of this handicap, the author of "Cybernetics" may be likened to a farm-to-farm census-taker who is extraordinarily intellectual and who has contributed to the science of enumeration, but who thinks of himself as one of the over-all census analysts in Washington. In the sciences of life—to which he made contributions—he is a biometrist rather than a biophysicist or biochemist, a psychometrist rather than a psychologist, a sociometrist rather than a sociologist, and so on. This is not to imply that his dissertations are dry: they sparkle! All we imply—all we assert—is that they betray a narrow viewpoint and make reading the book through and through a tiresome task.

And in your field, dear reader, in the field of Automatic Control—to which Wiener made important though extremely specialized contributions—Wiener's narrow viewpoint blinds him in two ways:

In some passages on Automatic Control, he writes like a theorist deplorably out of contact with the practical "gadgeteers" or "plumbers" who design automatic-control systems that WORK.

See page 114 (confusion between feedback and powerless repeat-back).

See page 115 (confusion between the thermostat and the building itself; "badly-designed" thermostat isn't the trouble; real cause known for four decades to us humble "plumbers," verified mathematically by Carnegie Tech's Emerson Pugh in *Physics*, Vol. 2, 1932, pages 93-98).

See also page 125 (wrong assertions about steering *real* ships, not mathematical ships).

In other passages on Automatic Control, his narrow viewpoint blinds him to "the forest" even more seriously than when he deals with nerves and cells. Passages starting on page 36:

"We are already in a position to construct artificial machines of almost any degree of elaborateness of performance. Long before Nagasaki and the public awareness of the atomic bomb, it had occurred to me that we were here in the presence of another social potentiality of unheard-of importance for good and for evil. The automatic factory, the assembly-line without human agents . . ."

"I have said that this new development has unbounded possibilities for good and for evil. . . . It gives the human race a new and most effective collection of mechanical slaves to perform its labor. . . . However, any labor that accepts the conditions of competition with slave labor, accepts the conditions of slave labor, and is essentially slave labor. The key word of this statement is *competition*. It may very well be a good thing for humanity to have the machine remove from it the need of menial and disagreeable tasks; or it may not. I do not know."

You, dear reader, are not beset by such doubts. You know that "the Machine Age was not free from evils but the Age of Instruments is making Technology a pure blessing."

"It cannot be good for these new potentialities to be assessed in the terms of the market, of the money they save; and it is precisely the terms of the open market, the "fifth freedom," that have become the shibboleth of the sector of American opinion represented by the National Association of Manufacturers and *The Saturday Evening Post*. . . ."

It CAN be good—it usually IS good—for automatization to be rated in terms of dollars saved. Cost-cutting means more and better products sold to more consumers at lower prices; hence upgrading of workers from drudgery to enjoyable jobs; hence higher real wages; hence more leisure for the entire population; hence more children able to go to high school instead of to the "dark satanic mills" of the Machine Age; hence record-breaking enrollment at Wiener's M.I.T.; hence more symphony orchestras, and so on. That's why *Instruments* takes pride in the theme "Instruments Cut Costs."

"Taking the second revolution as accomplished, the average human being of mediocre attainments or less has nothing to sell that is worth anyone's money to buy."

How can a student of history lack a sense of human progress? How can he fail to see the rise of the dividing lines between "superior" and "mediocre" and "inferior"? Does the author believe that all of us are like our prehistoric ancestors? Or is he assailing the majority of scientists, who point out that mediocrity is being increasingly subsidized by Government?

"The answer, of course, is to have a society based on human values other than buying or selling. To arrive at this society we need a good deal of planning and a good deal of struggle . . .

Those of us who have contributed to the new science of cybernetics thus stand in a moral position which is, to say the least, not very comfortable."

Well, dear reader, you and we who contributed to the old science renamed by Wiener feel differently: We stand in a comfortable moral position.

"We have contributed to the initation of a new science which, as I have said, embraces technical developments with great possibilities for good and for evil."

"We can only hand it over into the world that exists about us, and that is the world of Belsen and Hiroshima."

Wrong: it is also the world of loving fathers and mothers, of poets and

composers and sensitive artists, of belief in the Fatherhood of God and the Brotherhood of Man.

"We **do not even have the choice of suppressing these new technical developments. They belong to the age, and the most any of us can do by suppression is to put the development of the subject into the hands of the most irresponsible and most venal of our engineers.**"

Name-calling betrays weak case.

"**The best we can do is to see that a large public understands the trend and the bearing of the present work, and to confine our personal efforts to those fields, such as physiology and psychology, most remote from war and exploitation.**"

"**As we have seen, there are those who hope that the good of a better understanding of man and society which is offered by this new field of work may anticipate and outweigh the incidental contribution we are making to the concentration of power (which is always concentrated, by its very conditions of existence, in the hands of the most unscrupulous). I write in 1947, and I am compelled to say that it is a very slight hope.**"

This "new field of work" isn't new. It is not contributing to the concentration of power: many instrumenticians can cite examples of new companies—small and of the "happy family" kind—created by Instrumentation.

(2)

Now for a pleasant task—the second book.

This book is his gift to *more* than two classes of workers. The publishers' blurb (probably written by Wiener himself) states:

"**Directed toward the working communication engineer and the working statistician, this book . . .**"

but we enthusiastically add to this announcement the future instrumenticians who, whether as designers or as users, work to improve automatic-control systems or to apply in the best possible manner a given (special future "brain-type") automatic-control system to a given application—an application, of course, being not only a process but a ship, a circuit, a machine, a weapon, an airplane, a vehicle, etc. Since, in decades to come, there may be more instrumenticians than "communication engineers and working statisticians," and since other occupational groups, non-existent now but equally large in the future, may likewise use the powerful tool given to them by Wiener through this book, the name of Wiener may rank with those of the mathematical immortals of all time.

So it's a great pity that "Cybernetics" (written in 1947) was published a year before "Time Series," which probably was completed in 1944 or 1945 according to rumors quoting people who are said to have used it then. Perhaps the War Department held it up (and a cryptic passage on p. 24 of "Cybernetics," lines 15-19, lends credibility to this supposition); perhaps it was a publicity gag; but whatever the reason, the timing was egregious—well nigh scandalous. It's almost as if Einstein, having completed in 1905 all the mathematical details of the Special Theory of Relativity, should have written a sensational "teaser" book about Relativity in 1907 to be published and publicized in 1908; and then made his serious disclosure in 1909! Almost but not quite!; anyway, the juxtaposition of names is not invidious, for the author of "Time Series" ranks among the Princes of the Realm of Mathematics now ruled by von Neumann.

It's a pity, also, that this book should have been cruelly handicapped by four extra pouches of lead shot on each side of the saddle. We mean the eight extra words in the title, for there's no denying that "On Stationary Time Series" or some other four-word title would suffice if "By Norbert Wiener" were to follow it! In years to come, no doubt, its users will refer to it in two words: "Time Series."

We say "in years to come" because we have in mind tens of thousands of users, whereas only hundreds are using it or have been sufficiently trained to use it today.

Then why this flowery tribute in *Instruments?* Is it to butter up the Prof after smacking him on the noggin? No sir! there's nothing personal. We never met the Doc; he hasn't heard of a simple-minded gadgeteer. It's simply that the appearance of "Time Series" marks a great advance in the Science of Instrumentation—almost as great as if yesterday there were no electron tubes and, today, the tubes we now use were to be invented suddenly. It's simply that the author of "Cybernetics" and the author of "Time Series," though inhabiting the same body, are two persons.

And if there's anything personal—in the sense of sentimental or emotional—which makes us devote more space to Time Series" than would a cold-blooded decision on editorial space allocation, it's a feeling of indebtedness, of obligation—not to anyone in particular but to a profession. For nearly thirty years we have asserted in print and in debates that it was as impossible for "pure" mathematics to produce a control "brain" (making rational decisions) as it was to square the circle.

This is not a retraction. We admit, however—and cheerfully!—that the Queen of the Sciences, through her subjects the professional mathematicians, can contribute much more to Instrumentation than most of us "plumbers" ever dreamt of—*in ways that most of us never dreamt of.* And Wiener has made the FIRST contribution of this kind. This requires an explanation. The explanation, it is hoped, will itself be a contribution to the advancement of Instrumentation.

First, let it be borne in mind that although pure mathematics and applied mathematics are radically different, there is no sharp boundary between the two. At one extreme may be cited mathematical invention—or "conception"—like tensor calculus. It was because Einstein as a young patent examiner devoted several years to mastering tensor calculus that he could formulate his first relativity equations—and it may be argued that *these* are not "pure" mathematics because they pertain to the physical world. At the other extreme may be cited a counter or a draftsman's compass. (The counter began with the concept of Number; the compass or any curve-drawing device with the concept of the Continuum—eons before these concepts were named, of course!)

That there may have been other pure-mathematics contributions to Instrumentation before Wiener's is conceivable—but we believe it to be demonstrable only by going back to before the beginning of the formulation of Instrumentation in 1924 and citing the sextant, the isochronous pendulum, the Venturi section, etc. Certainly, some mathematicians did invent some instruments, but the Science of Instrumentation existed only as a number of different embryos—the rudimentary bodies of knowledge that were to become mechanics, optics, acoustics, chemistry, electronics, sociology and other ingredients of Instrumentation.

Furthermore, it seems to us that all citable examples would be applications—not mathematics per se. The Venturi tube (elegant example!) was first constructed by an American, two centuries after Venturi's death. And so on. The only possibility is that some mathematician at Bell Labs or RCA Labs or elsewhere (perhaps in Europe) may have made a pure mathematical invention for solving a measurement or control problem. (Control involves measurement: "To control, first measure" was one of the foundations of the Science of Instrumentation.) If so, this was not reported, to the best of our knowledge, in any mathematical journal or elsewhere.

Which is to say that Wiener's is the first DIRECT contribution, of a purely mathematical nature, to Instrumentation. This emphasized word "DIRECT" seems an utter absurdity, doesn't it? Yet it is the reason why we ask all Instrument Men to applaud the author of "Time Series" (and to stigmatize the author of "Cybernetics"). By "directness" we mean something like "applicability"—and to speak that way of an imponderable and intangible invention would seem to be discussing mere terminology. Well, it isn't mere terminology, but the regrettable present confusion of terminologies has a lot to do with it. If it weren't for this confusion, Wiener and his little group of intellectuals might not have coined a new word, for they would have known that Control is part of Instrumentation. They would have known it's not new. Your editor is in large part responsible for this confusion by having taken the easy road of good-fellowship and self-effacement when an intersociety situation arose—failing to recognize that situation as a crucial turning-point. Now, for the sake of harmony among the fields of mechanics, electricity, hydraulics, electronics, pneumatics, etc., we must confess:

In 1936, several pioneer instrumenticians were among those present at a meeting of a great engineering society. One of them, John J. Grebe, saw in a flash of genius the opportunity of *doing* what we all wanted: of organizing a committee to bring out in printed form the terminology of Instrumentation—a committee representing various fields but not including engineers employed by instrument companies (in order to avoid hurting feelings because companies used various painstakingly-produced terminologies) and not *representing* any society: only one unofficial Project. Even the word "committee" was discarded in favor of "group." The Group was immediately constituted and organized. It began work that evening and continued untiringly through correspondence and long-distance phone conversations. Differences were quickly reconciled. All final decisions were unanimous. Here are two of supreme importance:

(1) An automatic controller was defined as "A DEVICE" in recognition of the existence of electrical and electronic control systems without moving parts.

(2) Among the first definitions—THE first in one draft—was that of the Indication or Signal or Message or Intelligence or Information. The technical verbiage would bore you; the thing to bear in mind is that there was instant unanimity of opinion as to *including* this intangible thing, the measuring-element's Indication. This unanimity was a natural consequence of the first paragraph the Group had adopted at the very start, in which the Manual of Instrumentation was the only project or society named. And the first "basis-of-discussion" or "starting-point" definition of a controller as previously printed in the Manual had compared the "brains" of a controller to an executive depending on *the timeliness and correctness of the information* he receives. This was considered to be even more important than the "brain" and "nerve" and "muscle" analogies, because these are *things* in organisms and in instruments.

Then the great society, at whose headquarters the founder-members of this Group had met, appointed these founder-members (not the members later added, who had not been present) as an official Subcommittee.

Now let a curtain be quickly drawn over our sins of omission: the fact that we were hospitalized thirteen weeks in 1939 is not an excuse but an alibi. The upshot was the publication of a Control terminology which today is of international renown because of the importance of the great professional society, BUT in which:

(1) A controller is a "mechanism." This is logical and to the credit of the society, which—as you've guessed—is the ASME.

(2) The paragraph emphasizing the Indication or Signal, at the beginning of the Terminology submitted to the ASME by the Group, has been stricken out.

Your editor is largely to blame for the present confusion because in the last eight years his efforts at ending it have been confined to such means as correspondence and conversations. This is the first time these things are said in print. They must be said because

(1) A controller is a device and may be non-kinetic.

(2) The nature of the Indication or Signal or Intelligence or Information is of supreme importance—of such importance that you don't need a proof: this list of mere words conveys the whole idea to you—and you'll never forget it as long as you live!

Now you can see, just as clearly, why the mathematical tool in the book "Time Series" is a direct contribution to the Science of Instrumentation. There remains only for us to report to you the nature of this momentous contribution. We hope you don't expect a book review. About nine-tenths of the printed matter of the book is equations and only one-tenth "reading-matter." A review of the equations would best be done by a professional mathematician. Our review of the reading-matter is that its style is one of extreme modesty. (Again we assert that there are two persons in one body!)

A review of the book AS A TOOL is the one you want. Here it is. We start it by quoting Wiener—not in "Time Series" which is for highly trained mathematicians but in "Cybernetics" which is supposed to be for the layman. This is the opening of a chapter on time series and related subjects:

"There is a large class of phenomena in which what is observed is a numerical quantity, or a sequence of numerical quantities, distributed in time. The temperature as recorded by a continuous recording thermometer; or the closing quotations of a stock in the stock market, taken day by day; . . . all time series, continuous or discrete, simple or multiple. These time series are relatively slowly changing, and are well suited to a treatment employing hand computation or ordinary numerical tools such as slide-rules and computing machines. Their study belongs to the more conventional parts of statistical theory.

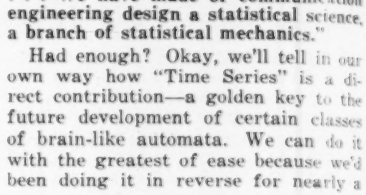
"What is not generally realized is that rapidly changing sequences of voltages in a telephone line or a television circuit or a piece of radar apparatus belong just as truly to the field of statistics and time series, although the apparatus by means of which they are combined and modified must in general be very rapid in action. . . . These pieces of apparatus—telephone receivers, wave filters . . . all in essence quick-acting arithmetical devices. . . . "

Then follow pages on: probability as in coin-tossing, "excess of information," "noise," probability distribution densities (normalized and un-normalized) an allusion to the Bell Labs "Vocoder" system of scrambling speech to foil eavesdroppers, etc. etc., all leading to the concept of a mesage homogenous in time or which is in statistical equilibrium constituting a time series. Then a discussion of cases where the entire past of a time series can be given in a set of countable quantities . . . That's a brief description of only one-third of that chapter in the first book which is *about* the subject of the second book.

Again quoting from "Cybernetics," here is a passage in the Introduction, mentioning specific problems the solution of which is provided by "Time Series":

"We attacked the problem of the design of wave filters . . . a message contaminated by extraneous disturbances which we call *background noises*. . . . We have made of communication engineering design a statistical science, a branch of statistical mechanics."

Had enough? Okay, we'll tell in our own way how "Time Series" is a direct contribution—a golden key to the future development of certain classes of brain-like automata. We can do it with the greatest of ease because we'd been doing it in reverse for nearly a



quarter-century. (In reverse means we'd been "proving" it couldn't be done.) Perhaps that old blackboard sketch of ours has already conveyed the general idea, so we needn't go on with our old stuff.

(But if you're a beginner—if you've never even read one of those profusely-illustrated and deliciously instructive booklets put out by controller manufacturers—you might look up the piece on "Now YOU are the controller" in the July 1930 *Instruments*, pages 431-440; also the one entitled "Why Automatic Controllers May Behave Like Human Beings" in the Nov. 1942 *Instruments*, pages 4598-4600.)

Another way we can "review" Wiener's great second book is by alluding to a subject which most of our VFW buddies will understand: ack-ack—which means automatized anti-aircraft artillery:

Human trackers keep the enemy aircraft sighted by turning the azimuth wheel and the elevation wheel; radar trackers do this automatically; in either case the Indication, the Intelligence, the Information to the unit that computes the firing data and aims the gun is inaccurate—because there's no such thing as absolute accuracy. Furthermore, this message is "noisy" by reason of gear-tooth backlash, jerky motions of human muscles or servomechanisms, etc. That's bad enough!

Worse yet, the electromechanical "executive" that receives this impure message doesn't know it's wrong and

Continued on page 500

Strain-gage Dynamometers *and* Indicators

By RICHARD E. CONOVER, Chief, Research and Development Branch,
Flight Test Instrumentation Section, Air Materiel Command, Dayton, Ohio

Introduction

SEVERAL refinements, applicable to strain-gage dynamometers and indicators in other fields than aviation, have resulted from the development of a new aircraft-control force-measuring system for the Flight Test Division, Hq., Air Materiel Command, Wright-Patterson Air Force Base, Dayton, Ohio.

It has long been standard practice to record flight performance data by a motion-picture record of a collection of standard or special aircraft instruments. These instruments are mounted in a common panel usually located in an enclosure, known as a "photobox," that incorporates provisions for a camera therein. Although the required frequency response for photobox recording is relatively low, such a device has given satisfactory results for most purposes. The development under discussion has been pointed to conform with this recording practice and to extend its usefulness into the realm of any strain-gage measurement.

The indicator most universally used in conjunction with strain-gage dynamometer for photobox recording has been the d-c. microammeter. The scale length on such an instrument is plus-and-minus 45 degrees of arc, whereas in this new system the scale length has been increased to plus and minus 360 degrees. Since the extension of scale length magnifies errors proportionally, little advantage is gained thereby, unless steps are taken with each component of the complete system to eliminate inaccuracies that would be tolerated in foreshortened scale equipment. This article deals with the methods found effective for improving the system's accuracy, principally through refinement in the design of the dynamometer mechanical elements and improvement in the temperature characteristic of the electrical circuits.

Dynamometer Design Considerations

In order that the force measured will be independent of load distribution, the dynamometers used in this system have been constructed to incorporate the double cantilever beam principle diagramatically idealized in Fig. 1A. In such an arrangement, assuming symmetry in beam dimensions and strain-gage locations, the strain actuating the gages is proportional to the individual reactions at the support, the sum of which is always equal to the applied load. If the strain gages are affixed and interconnected as in Fig. 1B the output of the bridge is a linear function of the total strain.

The simple knife edge shown in Fig. 1A is the ideal type of support as it establishes definite lengths for the beams and minimizes friction at their free ends. Both of these conditions are necessary criteria for stability in calibration. In practical applications it seldom is possible to use the knife-edge type of support without resorting to guides for maintaining assembly and alignment. Such guides introduce undesirable and variable amounts of friction. Anti-friction bearings have been used in lieu of knife-edge supports in the dynamometers discussed herein. Their use has resulted in a close approximation of the ideal support and provided a means of holding the elements of the assembly together.

It is equally important to maintain consistency in physical properties of the fixed ends of the beams. This is best accomplished by machining the anchorage and the beams from one solid piece of material with drastic changes in section at the transitions.

Minimizing Temperature Effects

In certain dynamometer applications in aircraft, usually other than control force, the strain gage installation is subjected to ambient temperature variations of plus-or-minus 60 C. Theoretically, bridge circuits are inherently self-compensating for temperature variations since all arms presumably expand or contract simultaneously by the same amount. However, perfect compensation is attained only when the *slope* of the resistance vs. temperature relation is identical for all the gages in the circuit. It can be shown that in such a system having a relatively poor temperature characteristic, the major effect is manifested by a zero drift in the bridge output rather than in a change in sensitivity.

Those applications where the temperature change is the greatest are invariably installations that will not permit the obtaining of a reference force reading to establish a drift threshold. This problem led to an investigation of the temperature characteristics of each individual component. Substitution of other standard materials for those components having bad temperature characteristics has resulted in a greatly improved temperature characteristic for the overall system.

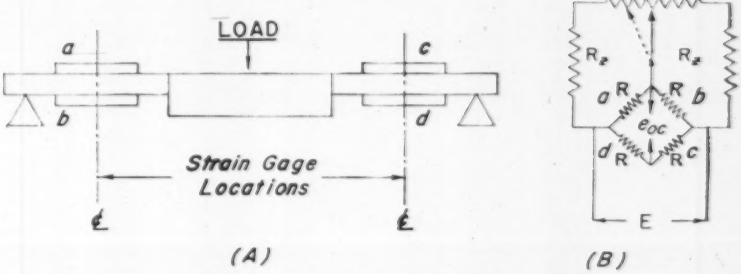
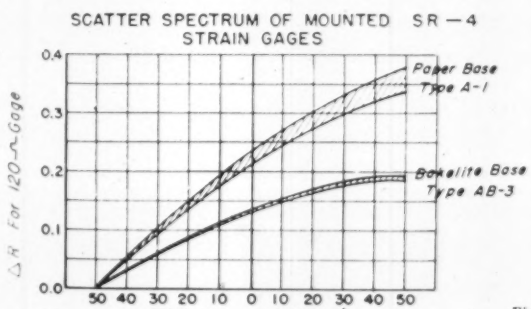


Fig. 1. Dual beam dynamometer system.



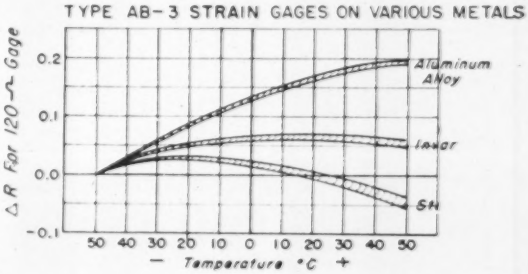


Fig. 2.

The temperature coefficient of a mounted strain gage is a function of three factors: first, the temperature coefficient of the wire material; second, its coefficient of linear expansion; and third, the deformation applied to the gage by the coefficient of linear expansion of the material on which the gage is mounted. The latter is a difficult factor to control precisely as it, in turn, is a function of the multi-layered bond consisting of cement and paper.

Figure 2A shows the scatter in measured resistance change for a number of Baldwin SR-4 strain gages attached to an aluminum alloy bar and subjected to temperatures ranging from –50 C. to 50 C. The Type A-1 gage is a rice-paper base assembly applied with ethyl acetate and celluloid cement. The Type AB-3 is Bakelite-impregnated paper gage applied with Bakelite cement. The width of the scatter spectrum was found to bear an approximate relation with the amount of indicator drift subsequently observed after the gages have been connected in a bridge circuit. Since this width confines the boundaries of the instantaneous slopes of the resistance-temperature characteristics, it is apparent that the temperature stability of the circuit is more dependent on having matched slopes than having matched absolute gage resistances. The drift obtained for the Type A-1 gage averaged about seven times that observed with the Type AB-3. A bridge consisting of four active AB-3 type gages yielded a temperature drift equivalent to 0.05 microinches per inch per degree Centigrade, or one half percent of full scale for a 100-degree Centigrade temperature change when the full-scale sensitivity is 1000 microinches per inch. If the dynamometers are made from high strength aluminum alloy (75S-T6), strains of double this amount are permissible design practice, and the percentage of full scale drift will be correspondingly reduced.

Further investigation into the use of different dynamometer structural materials is shown in Fig. 2B. It was found that the scatter spectrum was narrower, and the attendant drift less, when the gages are mounted on a material such as aluminum alloy or Invar that has a widely different coefficient of linear expansion than the gage wire. When the gages were attached to a steel bar which has approximately the same coefficient as the wire, a little greater temperature coefficient was observed.

Examples of Dynamometer Design

Examples of two dynamometers for specialized aircraft control force measurements incorporating these general design features are shown in Fig. 3.

Fig. 4 is a detailed view, less adaptor and pedal, of the first of such dynamometers which are used in pairs for measuring rudder control force. A ball-bearing assembly positions and supports one end of the pressure plate from the free end of the center cantilever beam. The other end of the pressure plate rests on two bearings located at the free ends of the two outer cantilever beams. The sum of the section moduli of the outside beams is equal to that of the center beam, and the summation of the strains within a single pedal is achieved by locating the gages as shown and connecting them in accordance with Fig. 1B. This dynamometer element, which fulfills all of the essential design considerations discussed previously, is universally adaptable to all types of aircraft rudder pedals.

The stick force dynamometer used for determination of elevator and aileron control forces, and shown in detail in Fig. 5, represents another application of the same basic design. Any force applied to the grip is transmitted to the stick adaptor through two cantilever beams. These beams, in order to attain good fixed end condition are machined from one solid piece of stock. Force is applied to the upper beam through a self-aligning bearing and through the walls of the stick adaptor to the lower beam by four balls spaced 90 degrees apart. In order to eliminate friction between these balls and their respective holes, it is necessary that the grip be free to rotate. This is accomplished by the introduction of the lower bearing. The outer surface of this lower bearing forms the inner race of a synthesized ball bearing that has the hardened ring as its outer race. The stick adaptor serves as the cage.

Two completely independent sets of strain gages, oriented in a simple bridge circuit, are used to measure the respective forces.

Servomechanism Type Indicator

The indicator used in this system is a servomechanism operating on the conventional friction-damped self-balancing potentiometer principle. It is a center-scale instrument with a scale length of plus-or-minus three hundred and sixty degrees on a three-inch diameter dial. An auxilliary sensing hand is provided to indicate direction of rotation. When it is used in an enclosed photopanel, remote indication for the pilot's observation is provided by a Magnesyn transmitter and receiver. While designed primarily for use in this strain-gage system, it is adaptable to other general types of

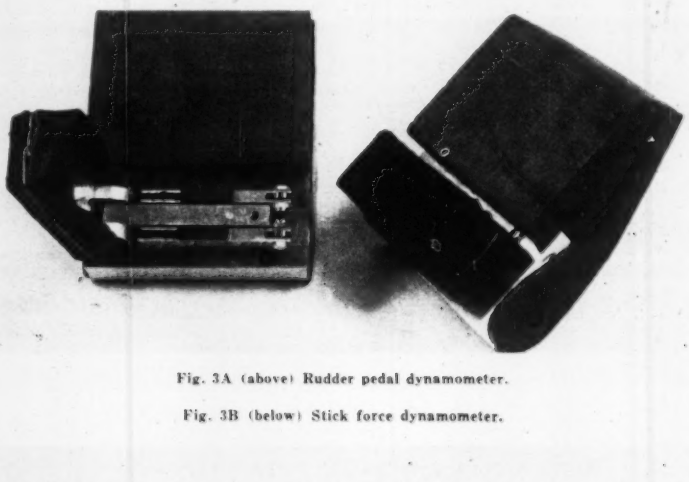
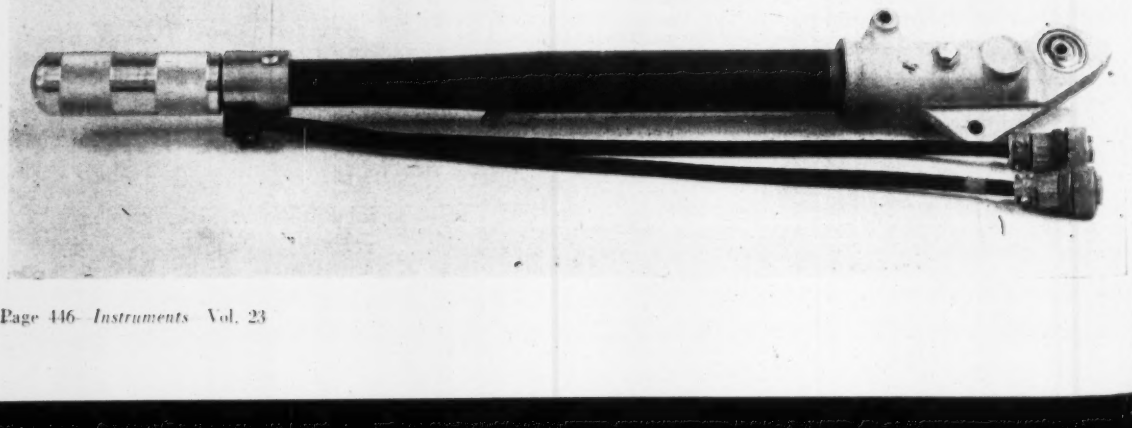
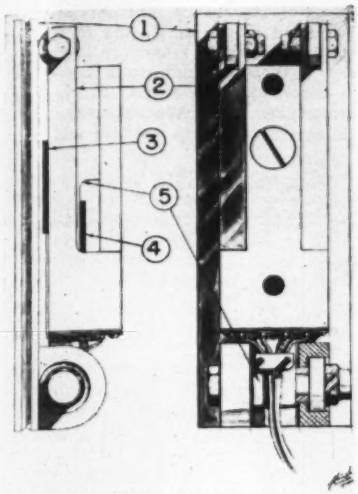


Fig. 3A (above) Rudder pedal dynamometer.

Fig. 3B (below) Stick force dynamometer.





1 PRESSURE PLATE
2 OUTER BEAMS
3 GAGES B AND D
4 GAGES A AND C
5 CENTER BEAM

Fig. 4

transducers employing variable-reactance or -resistance pick-up elements. The complete indicator is illustrated in Fig. 6. Supplementary diagrams showing its cross section and wiring schematic are given by Figs. 7 and 8 respectively.

A sensitivity adjustment is provided to allow the range in full-scale sensitivity to be varied from plus-or-minus 280 to 2400 microinches per inch with a four-active-arm 120-ohm bridge. The amplifier gain and mechanical elements have been apportioned to give the system a natural frequency of ten cycles per second. Typical frequency response and phase angle characteristics are shown in Fig. 9.

Conditions of service sometimes require that this equipment be subjected to wide temperature differentials after balancing; for instance, it often is necessary to install the amplifier in non-heated sections of the airplane where the zero balance is inaccessible after take-off. For this reason the current model has been engineered to allow an ambient temperature change over a range of plus-or-minus 55 C. with less than 1% of full scale drift.

Experience with an earlier version has shown that it is essential to use low-temperature-coefficient resistors in all components connected with the manual or motor-driven bridge-balancing circuits. In addition it has been found necessary to maintain good stability in the electronic amplifier, particularly with regard to wave shape. The positioning of the indicator is a function of the relative amounts of grid voltage applied to each of the discriminator tubes and it is necessary to maintain the status quo throughout the temperature range. This is particularly important when operating from a high-harmonic-content carrier supply such as the usual 400-cycle converter output. If the frequency characteristic of the amplifier changes, the symmetry of the output wave shape about the zero axis is likely to shift, and this will initiate a compensating movement in the indicator.

Two methods were considered for maintaining constant discriminator grid voltage ratio. The first made use of a wide-band amplifier, covering frequencies from 400 cycles upward, and stabilized by inverse feedback to maintain the frequency characteristic constant with temperature. The other method was to eliminate the higher

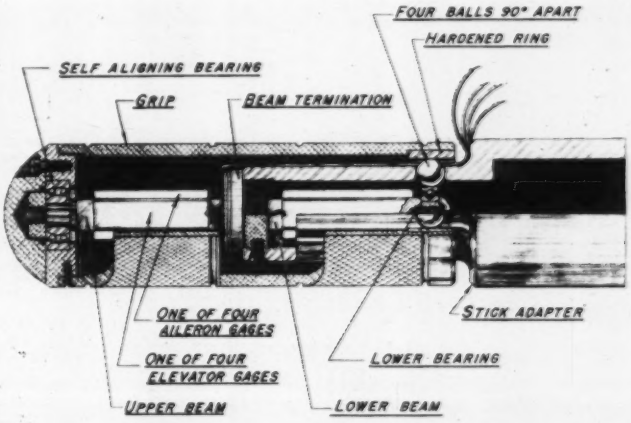


Fig. 5 Stick force dynamometer.

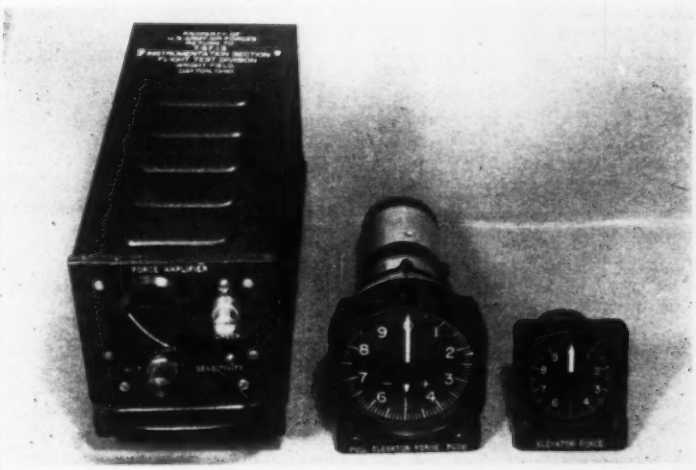


Fig. 6 Servo type indicator system.

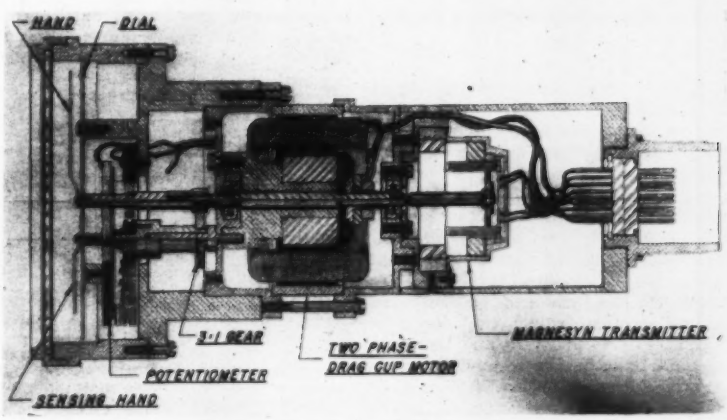


Fig. 7 Cross section servomechanism type indicator.

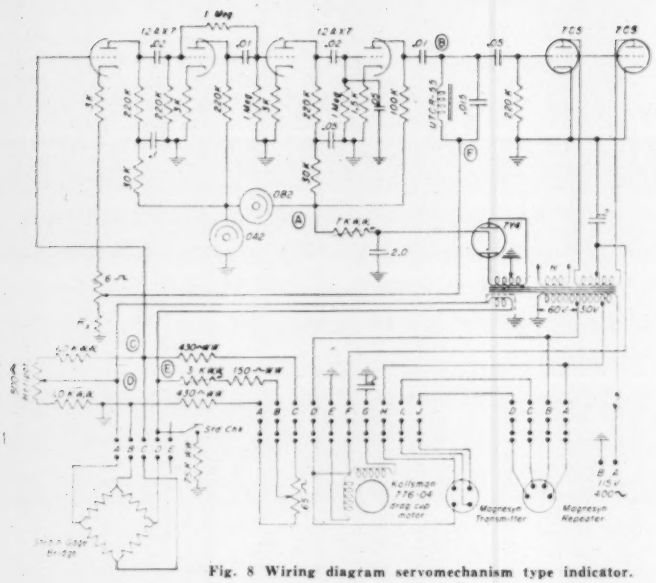


Fig. 8 Wiring diagram servomechanism type indicator.

frequencies by a frequency discriminating inverse feedback network. This latter method was chosen as being simpler while equally adequate. The gain of the amplifier of Fig. 8 is 30,000 at 400 cycles and is down 6 db at one octave off resonance.

Variation in Sensitivity with Strain-gage Resistance

The basic self-balancing potentiometer circuit consists of two elements of circuitry in parallel, either one of which is capable of producing an unbalance, or correcting an unbalance initiated by the other.

An unbalance in the circuit of Fig. 1A may either be created by changing one or more of the bridge arms R by an amount ΔR, or by moving the contact arm of the potentiometer. Equating the open-circuit voltages produced by either method of unbalance to simulate the condition where the unbalance created by one action is compensated for the other:

$$e_{oc} = E\frac{\Delta R}{R} = E\frac{R_2 - R_1}{2(R_2 + R_1)} \quad \cdots\cdots(1)$$

where $$R_1 = \frac{R[R_2 + R_p(1+a)]}{R + R_2 + R_p(1+a)},$$

and $$R_2 = \frac{R[R_2 + R_p(1-a)]}{R + R_2 + R_p(1-a)}$$

are the composite resistance of both arms for any position (a) of the contact arm.

Solution of the above equation yields the following second-order equation in (a):

$$2(\Delta R)R_p^2 a^2 - R^2 R_p a - 2(\Delta R)(RR_2 + RR_p + R_2^2 + 2R_2R_p + R_p^2) = 0 \quad \cdots(2)$$

one root of which gives the percentage of full-scale travel of the inductor in terms of the circuit constants and ΔR. For fixed values of R_s and R_p if their sum is large with respect to R it can be shown that the indicator's travel (a) is inversely proportional to the gage resistance. This solution neglects the shunt effects of the manual and automatic balancing components on the sensitivity of the gages. In this application since R_s is much greater than R_p a close approximation of the effective ΔR of the shunted gages is given by:

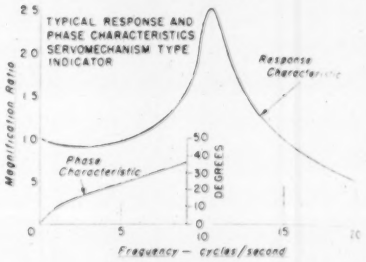


Fig. 9

$$R_{eff} = \left(1 - \frac{R_\alpha}{R + R_\alpha}\right)\Delta R_{gage} \quad \cdots\cdots(3)$$

This is the preferable value for use in equation (2).

This increase in sensitivity will be obtained at the expense of a decreasing rate of response, since the servo's error voltage per increment of travel is decreased. This requires that the gain of the amplifier be increased proportionally by adjustment of the feedback control. This increase in sensitivity, obtained as the bridge circuit resistance is lowered, has proven useful when it has been necessary to operate with extremely low strain conditions. Lower bridge circuits can readily be obtained by paralleling any number of standard gages until the sensitivity is as required.

A High-temperature Extensometer

By W. W. EITEL, Junior Instructor in Mechanical Engineering, Johns Hopkins University
and J. H. POTTER, Professor of Mechanical Engineering, University of Illinois

I. Introduction

In a high-pressure high-temperature flanged pipe joint it is important to know the bolt stresses at the time of assembly and under operating conditions. It is customary to measure the length of the unstressed bolts with outside micrometers or vernier calipers, and to establish the bolt stress in the completed joint by measuring the increase in bolt length. This method has been described by Petrie[1] and others. Many theories have been advanced on the changes in bolt and gasket stresses when the joint is brought to full pressure and temperature, but little has been published. The work of Salingre[2] indicated that large thermal stresses were induced in the bolts of a flanged joint on a superheated steam line, and that thermal stresses were present during the operating period as well as in the warming-up period.

When it was decided that such a joint should be set up and tested in the mechanical engineering laboratories at the Johns Hopkins University, one of the prime needs was for a satisfactory extensometer. A review of the instruments commercially available showed that a special design was called for and that the extensometer would have to meet the following specifications:

(1) Sufficient ruggedness to operate successfully under laboratory conditions.

(2) Simplicity of design to minimize shop costs and to provide ease of assembly.

(3) The part of the extensometer in contact with the bolts would have to "reach" over the insulated flange.

(4) The instrument would have to measure small changes in length, whether positive or negative, and to follow the changes with minimum time lag.

(5) The extensometer itself should be substantially free from temperature effects.

II. Extensometer Design

An extensometer was built following the design shown in Fig. 1. In essence it was a large pair of scissors, work-around knife-edge fulcrum E. In order to "reach" over the insulated flange, the distance from the fulcrum to the measured object was fixed at seven inches. To increase the accuracy of measurement, a 3:1 ratio of magnification was introduced between the indicator and the bolt. Dial gage G, having 0.0001-inch divisions, indicated the magnified length changes. Small weight H was used to keep the dial stem in close contact with the lower frame.

Temperature effects in the extensometer were minimized as far as possible. A radiation shield C was used to guard the knife edge. The actual bolt movement was brought to the frame by fused silica rods[3] 6 mm. in diameter shown at A,A. These members were of nearly constant length during the tests, as the average coefficient of linear expansion is only 0.00000051 inch per inch per degree C. in the range 20-500 C. Owing to their low thermal conductivity, these rods minimized heat leakage from the bolts

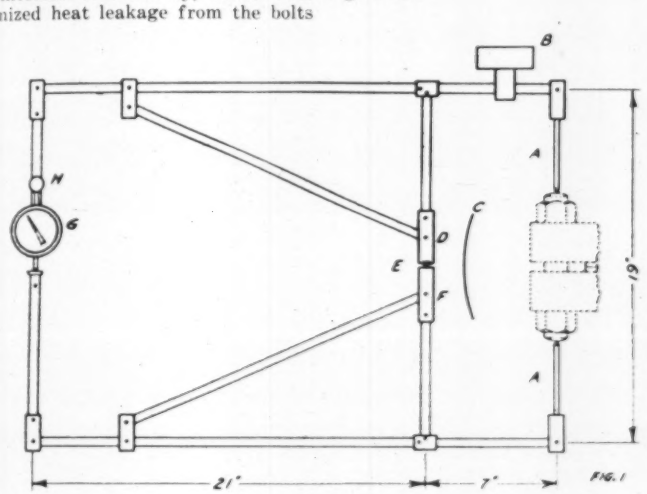


FIG. 1

to the frame and also kept their own average temperature (and hence their expansion) low.

The main frame was made of Invar[4] which was capable of only slight change in length over the temperature range to which it was exposed. The principal members were made of 0.5-in. 18-ga. Invar tubing; these were joined by Invar blocks made from 0.75-in. square bar stock. Lest the low thermal expansion properties of the Invar be impaired by welding, all block-to-tubing joints were pinned.

The unit was supported from a horizontal bar normal to block F. In operation, the lower half of the frame was located first, the silica rod being set in a conical recess in the bolt. The upper frame was then put in place. Two small coil springs (not shown) joined blocks D and F, positioning knife edge E. Counterweight B kept the upper quartz rod in intimate contact with the bolt. The dial gage was then attached and weighed. Some sluggishness was observed in the action of the dial gage. This was remedied by lubrication and by internal adjustments. In addition, a small electric buzzer, mounted on the support which carried the lower frame, reduced the time lag of the dial gage.

III. Test Method

In the design of the extensometer an effort was made to provide a 3:1 ratio of magnification between the dial gage and the quartz rod contact. A series of room-temperature tests were made to establish the actual magnification. An inside micrometer was provided with an extension rod to give an overall length of eight inches. Conical seats were provided in each end of this device which was inserted between the two quartz rods of the extensometer. Readings were taken on both the micrometer and dial gage for increasing and decreasing length increments. The micrometer was moved in steps of 0.01 in. over a total travel of 0.15 in. The magnification factor was found to average 2.93.

In order to determine whether the extensometer would work successfully under operating temperatures, a high-temperature calibration was made by means of a small electric furnace open on the ends so that a specimen could be held in the furnace by the quartz rods. In the furnace the heating elements were wound on an aludum cylinder so that the specimen was not subject to direct radiation from the heater coils.

The National Bureau of Standards was good enough to lend samples of a material for which that institution had already measured the thermal expansion properties. They also provided data on the average coefficient of thermal expansion between 20 C. and 500 C. in steps of 100 C. A test cylinder was made from this material, 0.1875 in. in diameter and 8 in. long. Conical recesses were made in each end, and at the mid-point a small radial hole was drilled for a thermocouple. To measure the temperature of the test cylinder, an iron-constantan thermocouple was located inside the bar and held in place with a piece of glass ribbon. Before the test, this thermocouple was calibrated against the boiling points of water, mercury and sulphur.

The test cylinder was located in the furnace and the two quartz rods were brought into contact with it. The open ends of the furnace were sealed with glass wool held in place by small asbestos-paper covers. Temperatures were read on a precision potentiometer, with the reference junction kept at the ice-point. The furnance temperature was controlled by varying the heater-circuit resistance; readings were taken on the dial gage and the thermocouple.

IV. Results

In Fig. 2 the average coefficient of thermal expansion has been plotted against temperature. The "standard" points, marked with circles, represent National Bureau of Standards values reduced to the Fahrenheit scale. The experimental points (marked by squares) have been jointed by straight lines in order to estimate values at the same temperatures as the "standard" points. Over the range in which this sort of interpolation is possible, the test values agree within about 0.08 percent of the standard. This is remarkable in view of the crudeness of this apparatus. Also the spread of the test points corresponds very nearly to that of the standard data.

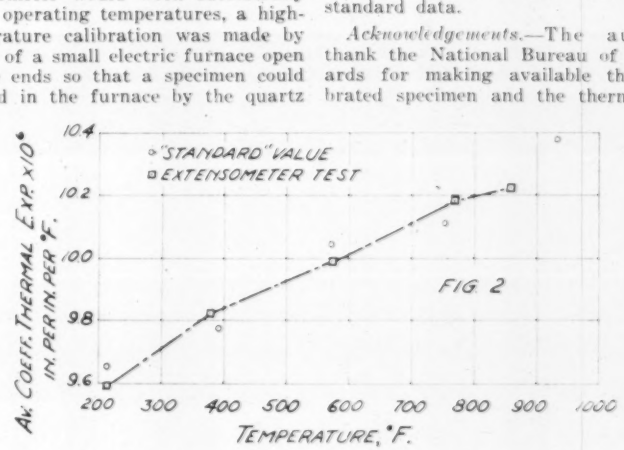


FIG. 2

Acknowledgements.—The authors thank the National Bureau of Standards for making available the calibrated specimen and the thermal expansion data for it. They also thank Mr. J. W. Peach, of the Johns Hopkins University, for his assistance and encouragement.

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Shooting *an* Electronic Circuit

By C. A. HARTUNG, Instrument Engineer, Sun Oil Co., Marcus Hook, Penna.

TROUBLE-SHOOTING in electronic circuits is a subject of such wide scope that it could be made the subject of a course lasting several months. Therefore, this discussion covers one procedure of trouble-shooting and the minimum of equipment required for service work. It is not expected that anyone reading this article will be able to go out and find all the trouble that may occur in circuits. The object of this article is to give a procedure which the author has found to work satisfactorily in a large number of cases where laboratory or elaborate testing equipment is not available.

The following tools and equipment are necessary for servicing:

Hand tools such as pliers, screw drivers, etc.

Tube checkers, voltmeter, ohmmeter, tube manual, and a color code for resistors and capacitors.

This equipment is the very minimum that is required and the instruments should be multi-range instruments, so that accurate readings may be obtained from 0 to 1000 volt a.c. and d.c. The d-c. ranges should have an input resistance of 20,000 ohms per volt, and the a-c. ranges not lower than 1000 ohms per volt. An ohmmeter with four or five ranges is required so that resistors from 2 or 3 ohms to several megohms can be measured.

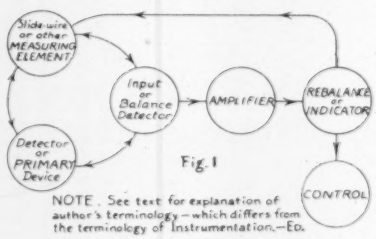


Fig. 1

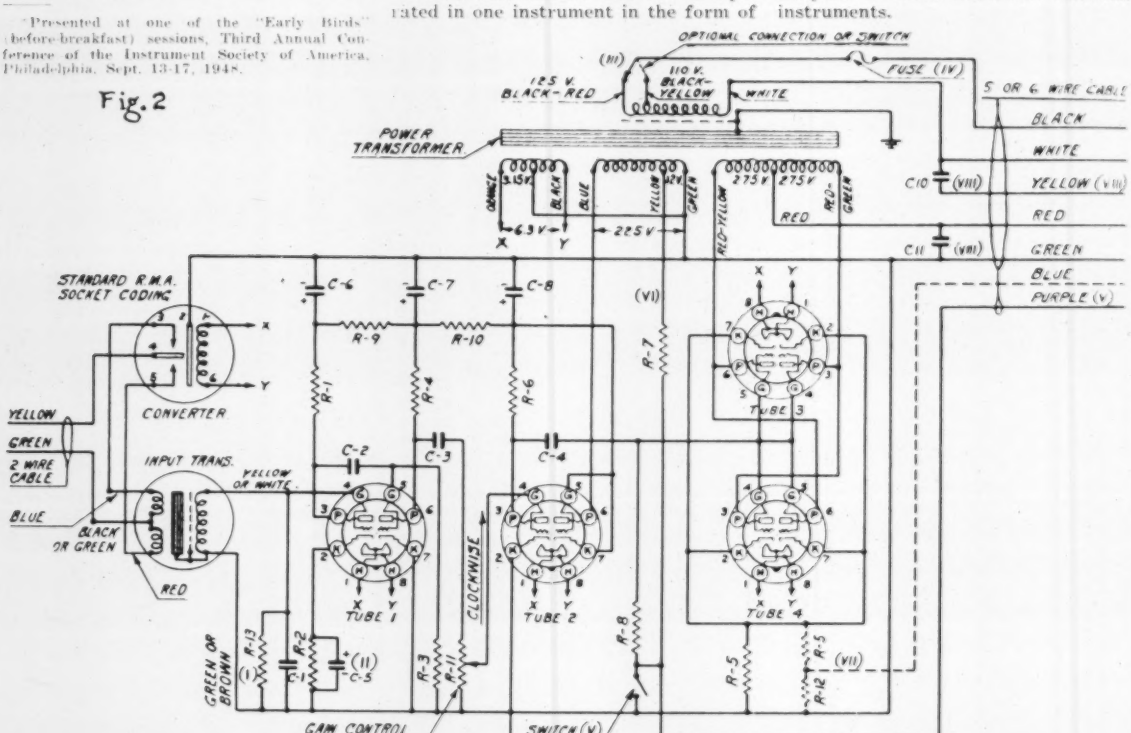
NOTE. See text for explanation of author's terminology—which differs from the terminology of Instrumentation.—Ed.

These instruments can be incorporated in one instrument in the form of a "multimeter," or they may be individual instruments. However, if the tube checker is a separate instrument, the resulting instruments are smaller and better fitted for field use where it is frequently difficult to use a large instrument. This is particularly true where instruments must be taken into the plant for voltage checks, etc.

The use of vacuum-tube voltmeters and oscilloscopes must be determined in each plant individually. They are useful tools in the hands of qualified men and will save time in locating the more difficult faults. If these instruments are available, an altogether different servicing procedure may be used than the one which will be described in the rest of this article. This procedure is to start in the early stages of the instrument and to TRACE THE SIGNAL through the instruments as has been outlined in several books for radio servicing with a signal generator and can readily be adapted to most industrial electronic instruments.

"Presented at one of the "Early Birds" (before-breakfast) sessions, Third Annual Conference of the Instrument Society of America, Philadelphia, Sept. 13-17, 1948.

Fig. 2



NOTES—

(I) "R-13" DOES NOT APPEAR ON AMPLIFIER 76020 WITH LINE VOLTAGE SWITCH AND FUSE, AND IS SOMETIMES OMITTED FROM OTHER MODELS.

(II) "C-5" IS SOMETIMES SUPPLIED AS A SEPARATE UNIT AND IS SOMETIMES INCLUDED IN MULTIPLE SECTION CAN-TYPE CONDENSER.

(III) AMPLIFIER 76020 INCLUDED A LINE VOLTAGE SWITCH ON UNITS BUILT THROUGH 1945

(IV) FUSE IS SUPPLIED ON 76020 AMPLIFIER WITH LINE VOLTAGE SWITCH, SLOW-BLOW FUSE IS SUPPLIED ON AMPLIFIERS 351921 AND 351959.

(V) SWITCH FOR ADDING OR REMOVING BURNOUT IS SUPPLIED ON 351921 AMPLIFIER ONLY. PURPLE LEAD NOT SUPPLIED ON SOME 351921 AMPLIFIERS.

(VI) "R-7" OMITTED AND YELLOW TRANSFORMER LEAD TAPED ON 351959 AMPLIFIER ONLY.

(VII) ARRANGEMENT OF "R-5" AND "R-12" USED ON 351959 AMPLIFIER ONLY

(VIII) "C-10" AND "C-11" AND YELLOW LEAD SUPPLIED ON 351921 AND 351959 AMPLIFIERS ONLY

The first step in the actual servicing of an instrument is to become familiar with it. Therefore all available literature should be read and the instrument examined at the first opportunity. On examination it will be found that most instruments can be broken down into the following components:

A detecting unit, a measuring unit, an input or conversion unit, an amplifier, a rebalance or indicating unit and sometimes a control system.

These units are present in even the most simple of instruments such as a voltmeter. In that case the detecting unit would be the moving coil. The measuring unit would be the permanent magnet and hair spring. The above units convert the electric current into a motion which is amplified by the pointer and indicated on the scale. These units are also present in a flowmeter where the orifice plate detects the flow, the mercury manometer measures the amount of flow and the input or conversion unit, which is usually a float, converts it into a linear motion. This motion may or may not be amplified by the indicating unit.

Fig. 1 shows a conventional arrangement of the above-listed components. Any or all of them may be an electronic circuit. The preliminary study of the instrument should be continued until the service man is thoroughly familar with the location and the operation of the above-listed units, and how the measured variable affects the instrument in normal operation. This should be done because it is much easier to find trouble when the normal operation is understood, as any faulty operation will be recognized as such when it occurs.

The components to be stocked as replacement parts may be selected at this time, and the minimum number will include a full set of tubes. The number of other parts to be stocked will depend on the number of instruments in service and the amount of trouble expected from them.

Fig. 2 is a schematic diagram of the electronic circuit used in a well-known instrument. This diagram will be used as an example for finding trouble in a circuit. This circuit includes the detector shown in Fig. 4, an amplifier in Fig. 5 and, when a motor is connected to the output as in Fig. 6, the rebalance system.

The operation of the unit is as follows:—

A d-c. voltage is applied to the input and is converted into a 60-cycle a-c. voltage by the converter and input transformer. The a-c. voltage is applied to the grid of the first tube of the amplifier sections. The amplifier section is contained in tubes 1 and 2 and there are three stages of voltage amplification. The output of the voltage amplifier is applied to the grids of the output stage which causes a rotation of the motor. The directional rotation of the motor is determined by polarity of the input voltage. If the polarity is as shown in Fig. 4, the motor will rotate in one direction; if the polarity is reversed the motor will rotate in the opposite direction.

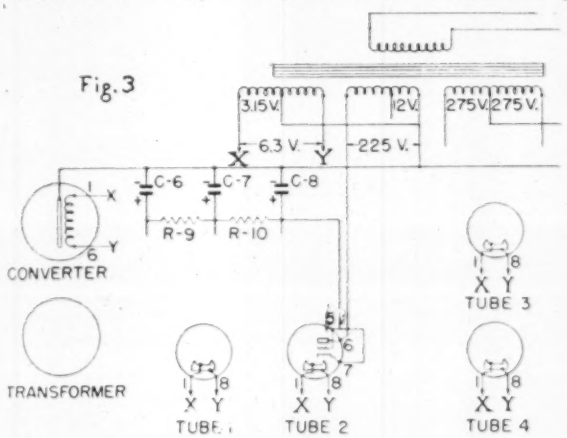


Fig. 3

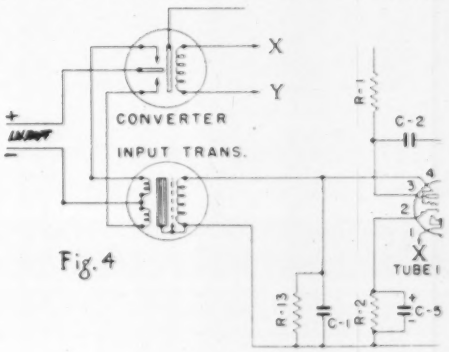


Fig. 4

In servicing this unit the first step is to check the tubes, in the usual way.

The second step is to check the plate supply and the heater circuits. These circuits are shown in Fig. 3. They consist of the power transformer, one-half of tube No. 2 which is used as a rectifier and the associated resistors and capacitors shown in the diagram. The quickest way to check the plate supply is to measure the voltage across capacitor No. 6. If the plate voltage is present at this point it means that the rectifier section and the filtering section made up of the capacitors and resistors are satisfactory. The heater circuit is from the power transformer to all the tubes and the converter. The connections are made between all the X's and all the Y's. This is the customary practice for showing heater and filament circuits as it eliminates the lines showing the connections between these points and makes the diagram easier to follow.

After the plate and filament supply has been checked and found satisfactory, the actual operating stages of the instrument should then be tested. In this case it can most readily be done by connecting the motor to the output as shown in Fig. 6; and the output stage tested by applying a 60-cycle voltage to the grid of the output tubes. Here is where a preliminary study of the instrument will prove very useful, as that will show that the voltage on the grids of the output tubes for rotation of the motor is approximately 5 volts and 2 to 3 volts will produce slow rotation. This voltage can be obtained from one-half of the heater winding which is 3.15 volts connecting from X to the grids and will produce rotation in one direction, while connecting from Y to the grids will reverse the rotation.

If this test does not produce rotation of the motor, the transformer voltage, resistors and the soldered connections should be examined and tested, as the trouble is undoubtedly in this stage. However, if this stage is satisfactory the third stage of voltage amplification, which is one-half of tube No. 2, should be checked.

This stage is checked in a similar manner as the output stage. The a-c. voltage from the heater winding is applied to the grid of the tube and rotation of the motor should be produced as described above.

This procedure of applying the a-c. voltage is continued on the first two stages until the faulty stage is found. When applying the a-c. voltage does not produce rotation of the motor, that stage must be checked completely or until the fault is found.

If all the stages of amplification are operating, then a d-c. voltage must be applied to the input, as shown in Fig. 4; and in this manner a fault in the converter or input transformer will be located.

With this method, the instrument has been checked with eight or nine tests excluding those necessary when the individual stage has been located, and at the most, fifteen tests will be necessary to find the faulty components. In this manner, the fault is located much quicker than starting at one part of the chassis and checking each individual component as you come to it.

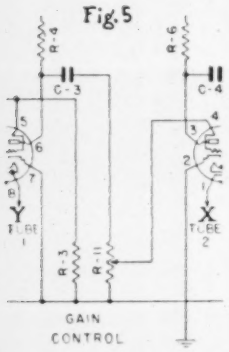
This procedure of checking by stages can be applied to almost any instrument. The requirements are as follows:—

An output device must be connected

to the circuit and a means of supplying a signal to the grids of the stages. This signal will vary from a d-c. voltage to high frequency a.c., depending upon the instrument. Therefore it is advisable to have a test instrument which will supply this signal if it is not readily obtainable as it was in the case of this circuit.

When a number of instruments have been checked, the above-described procedure may be simplified if experience shows that a single stage or even a single component is more subject to failure than the others. Also, some components have a shorter life than others. The best example of this are the tubes; their life is so short that they are inserted into the circuit by means of the prongs and tube socket. In general, the type of component with the next-shortest life will be the electrolytic capacitors which are frequently used in the plate supply. This statement may be contested by some people, but the author has found that after four or five years electrolytic capacitors fail quite frequently. Paper capacitors, transformers and most resistors have a very long life when operated within the manufacturer's ratings.

Fig. 5



The most difficult failure to find is the intermittent failure and, although there are many causes of this type of failure, by far the most common are poor soldered connections. These are found by visual examination or by pulling on the leads until the poor joint is found.

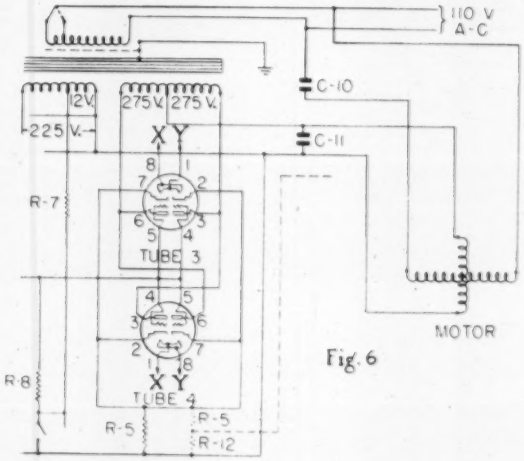


Fig. 6

QUESTIONS

1. *Is the additional cost asked by the manufacturer for replacement parts justified or should one buy from the corner radio store?*

It is impossible to give one short answer which will fit all cases, as it depends entirely on how and where the component is used and each case must be determined individually. However, in the input circuit of high-gain amplifiers and other very sensitive instruments, or where high stability is required, it is advisable to order from the Instrument Company as they often select or have special specifications for the components.

2. *Is it not best to purchase electrolytic capacitors from the instrument manufacturer because the film may have deteriorated until the proper voltage may not be produced across it? This is particularly true of a cathode by-pass capacitor.*

If an electrolytic capacitor has been on the shelf for a year or more, the rated voltage should be applied to the capacitor before installing it in the circuit. A resistor should be connected in series with the capacitor when the voltage is applied. This precaution should be taken whether purchased from an instrument manufacturer or a corner radio store.

ACKNOWLEDGMENT

The writer wishes to thank the Brown Instrument Company for supplying the schematic drawings used to illustrate this article.

A Slide Rule *for* Relief Valve Sizing

By M. M. FROMM, Greensburg, Penna.

THE equation used to calculate relief valve sizes for oil vapor is as follows:

$$A = \frac{W \times (T)^{1/2}}{306 \times P \times (MW)^{1/2}}$$

where A is relief valve orifice area in square inches; W is pounds per hour of oil vapor to be relieved; P is maximum vessel pressure, psia; T is absolute temperature at valve inlet (deg. F. plus 460); MW is molecular weight of discharged vapors.

Where frequent solution of this equation is required, a nomogram is usually used. A more convenient method, using a slide rule with special scales, is presented here. The rule is shown in the photograph.

It is constructed by gluing logarithmic graph paper over the scales of a cheap 12-inch slide rule. The W and P scales are full-scale 3 cycle. The T and MW scales are half-scale 3 cycle, inked in with India ink. The A scale is full-scale, with the standard orifice letter designations inked in. The index A is inked in over 306 on the P scale. After the scales are glued in place, they can be protected with a coat of clear shellac.

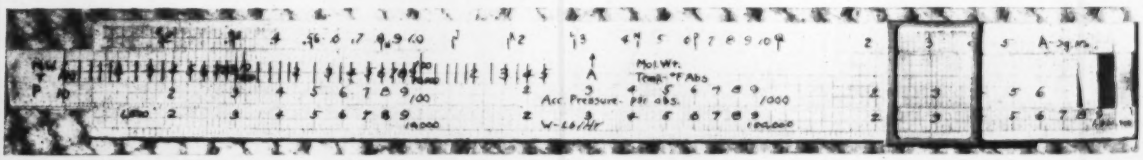
An example will illustrate its use: Relieve 50,000 lb./hr. of oil vapor, of average molecular weight 250, at 500 psia and 700 F.

(1) Set 500 psi abs. over 50,000 lb/hr.

(2) Move the hairline to 700+460 = 1160 F. abs.

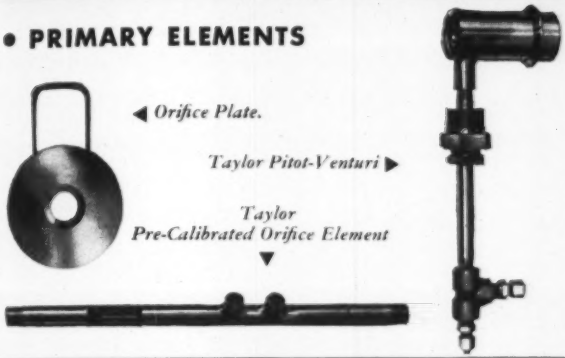
(3) Slide the stick till 250 mol. wt. is under the hairline.

(4) Read over the index A an area of 0.7 sq. in., for which an H orifice is required.



LET TAYLOR HANDLE YOUR FLOW PROBLEMS

• PRIMARY ELEMENTS



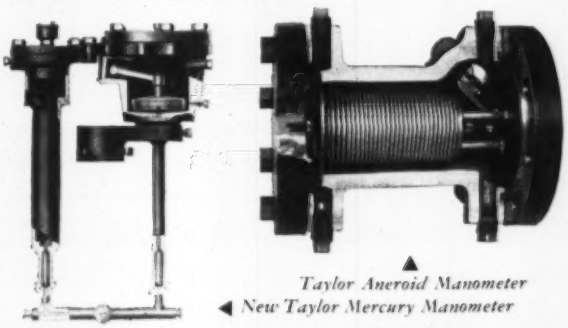
◀ *Orifice Plate.*

Taylor Pitot-Venturi ▶

Taylor Pre-Calibrated Orifice Element ▼

(1) Thin and thick type Orifice Plates from 2 to 24" in all standard materials. (2) Pre-Calibrated Orifice Assembly for high-accuracy with pipe sizes less than 2" are a "Specialty of the House" with Taylor. (3) The new and exclusive Taylor Pitot-Venturi Flow Element which produces greater differential with practically no pressure loss—7 to 10 times greater than by the conventional Pitot Tube. (4) Also standard Venturi Tubes. (5) Flow Nozzles from 3 to 14" in all standard materials.

• FOR MEASUREMENT

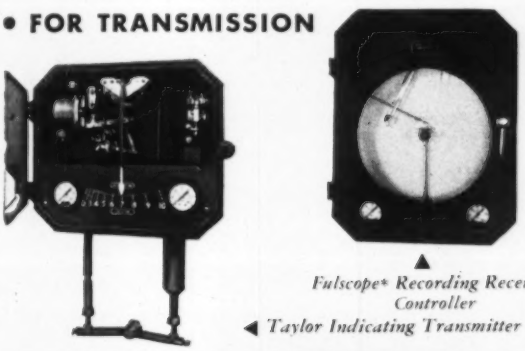


▲ *Taylor Aneroid Manometer*

◀ *New Taylor Mercury Manometer*

(1) New Taylor high-accuracy Mercury Manometer which features Teflon bearings, high energy output, submerged check valves, ½ of 1% accuracy, an adjustable leakless damping unit, and interchangeable range tubes for continuous ranges from 10 to 533 inches of water. (2) Taylor Aneroid (Mercury-less) Manometer, available in All-316 Stainless Steel or Cast Steel, accurately measures flow of hard-to-handle corrosive materials. No mercury to replace, no stuffing box. Sealing fluids or blow-back systems seldom needed. Long service. Easy cleaning. Easy range changes. Both Manometers available with Square Root Integrators.

• FOR TRANSMISSION



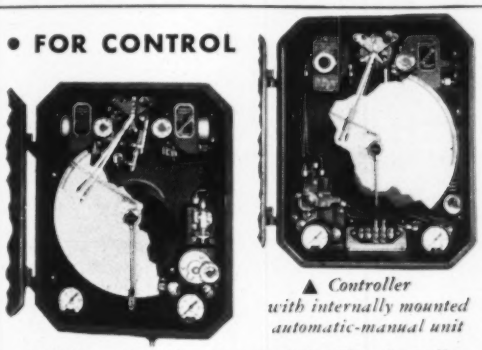
▲ *Fulscope* Recording Receiver Controller*

◀ *Taylor Indicating Transmitter*

Taylor Remote Transmission Systems accurately, quickly, economically, and safely transmit rate of flow to conveniently located point. Transmitters can be indicators, recorders or controllers. High accuracy—systems are calibrated to within ½ of 1% accuracy. High speed—only 2-second lag in 300 feet. Gives central control of widely distributed processes at one convenient point. Concentric dial transmitter with Mercury Manometer also available.

*Trade-Mark

• FOR CONTROL



▲ *Controller with internally mounted automatic-manual unit*

▲ *Fulscope Recording Pneumatic-Set Flow Controller*

Indicating or recording controllers in single or double duty form, with adjustable sensitivity or automatic reset. Ratio Flow Controllers with two Manometers attached. Control point may be adjusted by any other process variable. Pneumatic-set controllers whereby control point can be pneumatically adjusted from any remote location. Internally or externally mounted automatic to manual units.

• • •

For complete details, write for new Flow Catalog 98175, or ask your Taylor Field Engineer. He'll show you how Taylor Instrumentation can help you solve *any* flow problem. Taylor Instrument Companies, Rochester, N. Y., and Toronto, Canada.

TAYLOR INSTRUMENTS MEAN ACCURACY FIRST

INSTRUMENTS ON THE MARCH

Testing by the National Bureau of Standards

WASHINGTON, D. C.—The National Bureau of Standards receives many inquiries from industry and other sources regarding the scope of its testing program, the type of tests it makes and the fees it charges for this service. A new circular, *Testing by the National Bureau of Standards*, has just been published which fully describes the Bureau's test policy, presents general information on testing, and lists fees for most of the test work done.

The Bureau does not compete with qualified commercial testing laboratories, nor does it have the authorization, funds, or facilities to do general testing for the public. Fees listed include those for tests on electrical standards and instruments; standards of length, mass and time; pyrometers; fuels; radioactive standards; mechanical instruments; and optical instruments.

Circular C483, 93 pages, is available from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., at 25 cents a copy. Remittances from foreign countries should be in United States exchange and should include an additional sum of one-third the publication price to cover the cost of mailing.

Radioactive Tracers Used to Study Plating Process

WASHINGTON, D. C.—A better understanding of the mechanism of electrodeposition in chromium plating has resulted from recent studies by Fielding Ogburn and Abner Brenner of the National Bureau of Standards using radioactive tracer techniques. By tagging either the trivalent or the hexavalent chromium ion in a chromic acid plating bath with radioactive chromium 51, it was conclusively shown that metallic chromium is deposited out of the bath from the hexavalent state rather than from the trivalent state, as had previously been suggested. In addition to solving a long-standing problem in electrochemistry, the Bureau's work has demonstrated the utility of tracer methods as a tool for research on industrial plating processes.

Radioactive tracer techniques at the NBS provide a useful tool for studying the mechanism of chromium plating. Mrs. Lee Couch of the Bureau staff is shown placing a Geiger counter inside a tube upon which radioactive chromium 51 has been deposited. The counter and radioactive tube are kept within the radiation shield of lead bricks (right) while the amount of gamma radiation emitted by the deposit in a given time is recorded on the scaler (background) attached to the counter. By tagging either the trivalent or hexavalent chromium ion in a chromic acid plating bath with the radioactive chromium isotope, it was definitely established that metallic chromium is deposited out of the bath from the hexavalent state rather than from the trivalent state, as had previously been suggested.

Analog for Oil Industry

NEW YORK, N. Y.—An automatic "thinking" device for use in the oil and gas industry, which can figure out the performance of multi-component factionating towers in a fraction of the usual time has been developed at Northwestern University, Evanston, Ill. This analogue computer, now in operation, was described here at the Annual Winter Meeting of the American Institute of Electrical Engineers.

According to O. W. Goetz and J. F. Calvert, of Northwestern, the new machine will ease considerably the "tedious trial and error computations that have been employed in designing and pre-determining the performance of multi-component fractionating columns."

The machine, according to the authors, can be employed not only on the design of new equipment, but also on the study of possible design and feed variations which might be made in existing fractionation columns.

Radar-like Instruments Detect Speed Violators

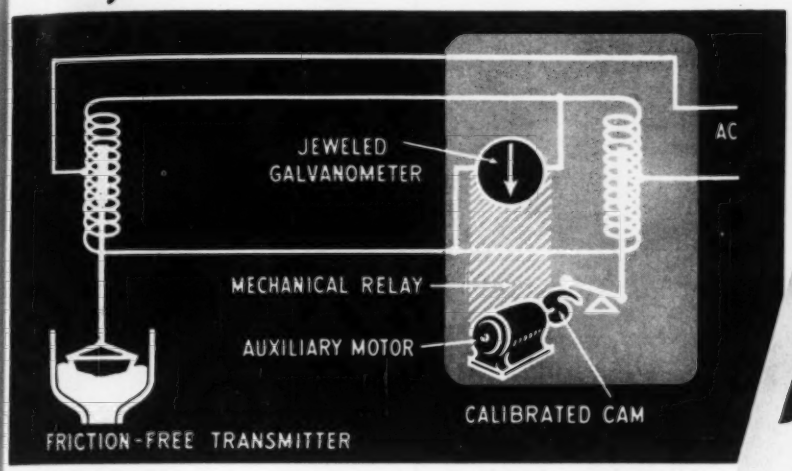
LANSING, MICH.—The Michigan State Highway Department's policy of developing modern methods of traffic control is evidenced in the recent purchase by the Department of a radar speed detector—a precision instrument that will accurately and instantaneously determine the speed of moving vehicles. This "Electro-matic radar speed meter" is the most modern piece of equipment yet developed by radar engineers. It is portable, highly accurate and far superior to the present method of recording vehicle speed with mirrors and stop watches.

For operating convenience, the new instrument is in three parts: a transmitter-receiver unit, an indicator-amplifier unit and a power unit. The transmitter-receiver unit is located near the roadway adjacent to the vehicles to be detected. The other two units are placed nearby at the convenience of the operator.

The speed meter utilizes microwave radiofrequency radiation beamed at the advancing or receding vehicle in the operating zone and reflected back from the vehicle to the transmitter-receiver. The instantaneous true speed of the vehicle is read directly in the indicator-amplifier unit. Pro-

SKI JUMPERS TIMED AT 50 MPH AT TAKEOFF—For the first time the speed of ski jumpers, as they took off from one of the country's highest jumps, was electrically measured and it was found they traveled at top speed of 50.4 mph. The tests were made at the Intervale Olympic 65-meter jump at Lake Placid by General Electric during the World's Championship games (Feb. 5). Engineers installed a time interval meter and two parallel light beams, eight feet apart, at the lip of the take off. The time between breaks in the two light beams as the skiers came down the "shoot" was registered in miles-per-hour. Before these measurements were made, guesses by the skiers themselves averaged from 35 to 80 mph. Official timing showed the average speed of the 40 international skiers to be 48 to 49 mph.

Why HAYS-PENN FLOW METERS



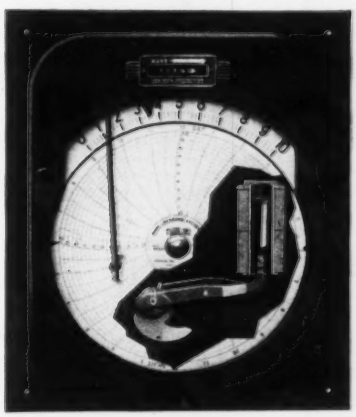
Stay ACCURATE

- ***The friction-free transmitter acts only as a pilot.....***
- ***Actuates an external motor drive that does the work***

An extremely difficult metering job provides an ideal demonstration of the dependable accuracy and freedom from maintenance built into Hays-Penn Flow Meters.

Unlike most flow meters, the sensitive measuring circuit is relieved of all work of indicating, integrating and recording.

For durability, readability, reliability—specify Hays-Penn Flow Meters.



You'll Want This Book

For full information on these modern electrically operated flow meters—how they are made, how they work, how they keep their accuracy through long continuous service—send for Bulletin 49-800. It's a "must" for every up-to-the-minute file.

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Michigan City 8, Indiana

Please send me Bulletin 49-800 which describes the Hays-Penn Flow Meters.

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AUTOMATIC COMBUSTION CONTROL • BOILER PANELS • FLOWMETERS • VERIFLOW METERS AND VERITROL • GAS ANALYZERS • DRAFT GAGES • COMBUSTION TEST SETS • CO_2 RECORDERS • ELECTRONIC OXYGEN RECORDERS • AIRFILTER GAGES

vision is also made for the connection of auxiliary equipment which records, in graphic form, the speed of every passing vehicle, furnishing a permanent record of the readings which are simultaneously shown on the meter.

The instrument operates interchangeably from a standard six-volt automobile storage battery of 120-volt alternating current. It is quickly set up at the desired location at the roadside and is immediately ready for operation. The operating zone extends for about 150 feet in front of the instrument. The speed range is up to 100 mph.

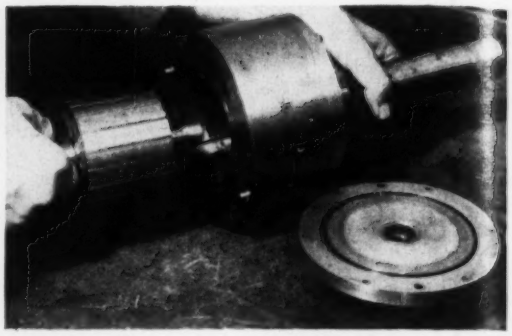
This new system will enable the Department to accurately determine the speed movements of all of the vehicles passing within the checking area. Under the system presently being used, it is possible to check only those vehicles which are spotted by the operators within their given checking points. Accordingly, it will not only speed up traffic checks but also will eliminate human errors that naturally develop through stop-watch checking. The graphic recorder will enable the operators to more easily record the speed of the different types of vehicles, such as passenger cars, trucks, trailers, buses, etc.

Improved Magnetic-fluid Clutch

SCHENECTADY, N. Y.—A liquid which can instantly change to a solid and then return to a liquid again is the basic feature of an improved magnetic-fluid clutch built by General Electric Company engineers. Only six inches long and six inches in diameter, the device is capable of carrying enough power to lift one ton 1,000 feet per minute. It has interesting possibilities in servomechanisms commanded by low-power instruments.

The G-E magnetic-fluid clutch is still in the laboratory stage, it was emphasized, and commercial possibilities have not yet been explored. Consisting of two metal cylinders, each able to rotate independently on the same axis, it transmits rotary power from its source to its load. The cylinders are separated by a magnetic mixture of oil and finely-divided iron powder. When the unit is energized, the fluid instantly solidifies, making a rigid connection between the two cylinders.

Power can be applied to the load and removed from it easily by the clutch operator. Degrees of rigidity of the magnetic fluid can be obtained by regulating the current, so that the clutch can be allowed to slip if necessary.



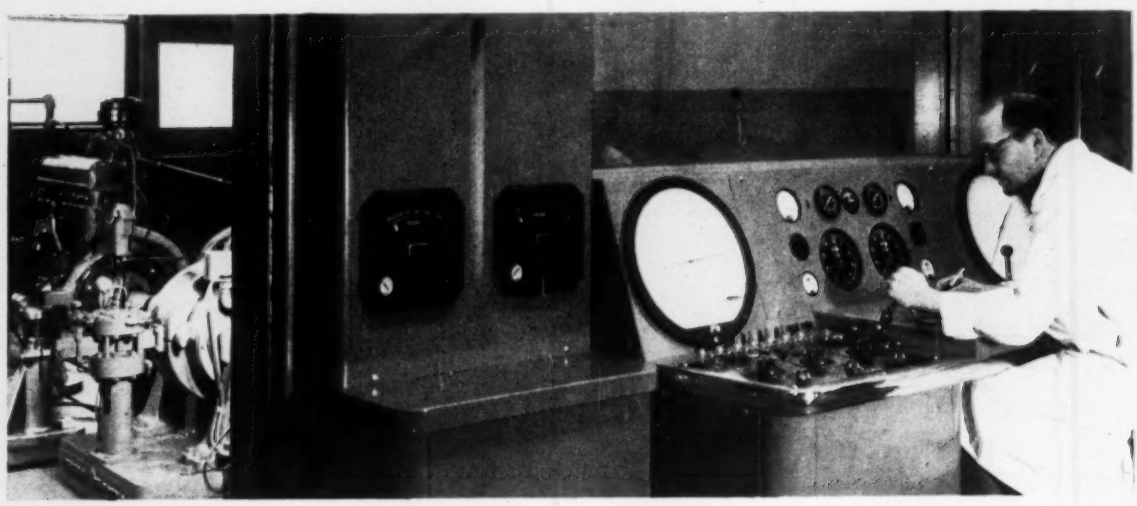
Kenneth E. Wakefield and Mason Kronick, development engineers, worked with the same basic type of clutch developed by the National Bureau of Standards. They have equipped their model, however, with rectangular teeth on the surfaces of its clutch faces. The G-E engineers have found that their small clutch, equipped with teeth, will carry a heavier load than one not so equipped.

Remote Control of 22 Cameras in Two Airplanes

NEW YORK, N. Y.—An airborne synchronized motion picture camera recording system for collecting photographic data, employing two airplanes, 22 motion picture cameras operating at the same time, remote control, dials and push-buttons, was reported here at the Annual Winter General Meeting of the American Institute of Electrical Engineers in the Hotel Statler.

This system, described in a joint technical paper prepared by Viola J. White and Sidney J. Horwitz of Northwestern University, Evanston, Ill., was developed in the University's Aerial Measurements Laboratory, for use in gathering data recorded on instruments and dials during actual flight.

The 22 motion picture cameras can be so controlled and designed that the operators have only to turn on the power switch, dial a number and push buttons designated "ready," "start," and "catalog-stop." The cameras in the remote plane are controlled through a frequency-modulated radio

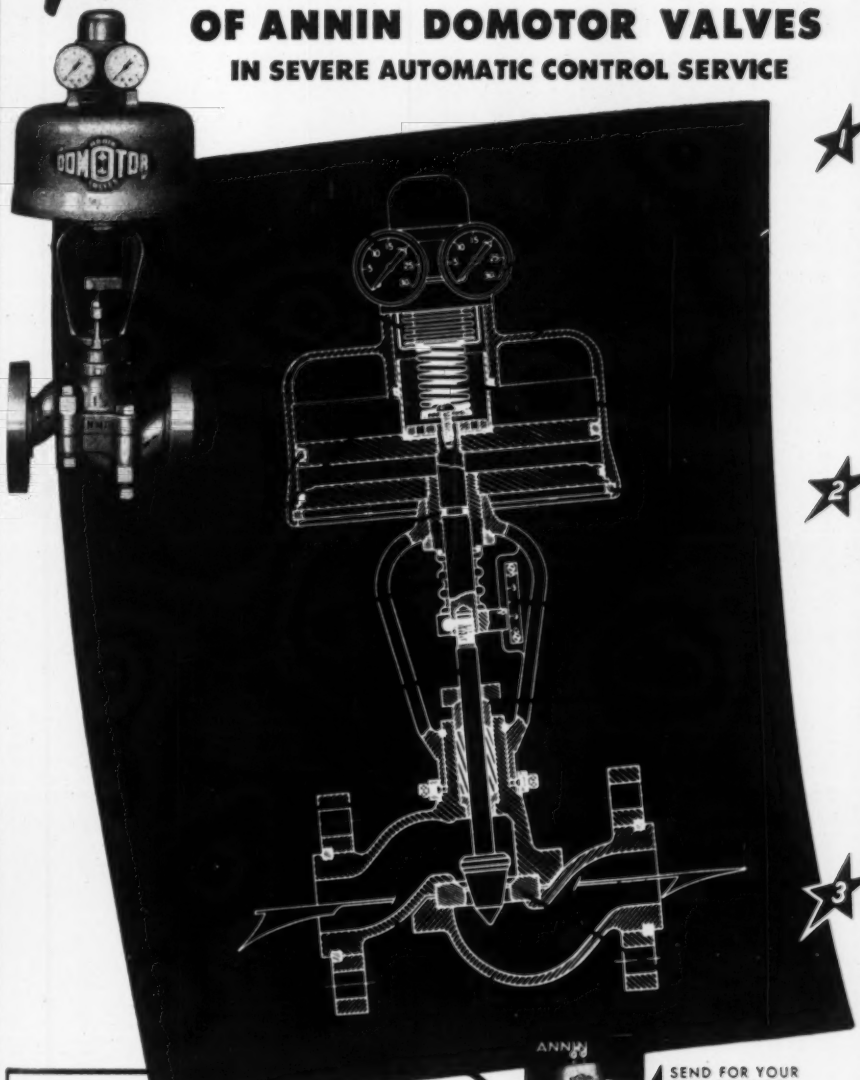


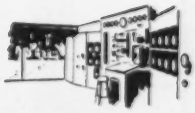
TRUCK-MOTOR ENDURANCE-TEST INSTRUMENTATION. Bearings and other engine parts—pistons, rings, valves, timing gears—"get the third degree" in a new endurance test program employed by a leading commercial vehicle manufacturer. Engines are operated above normal governed speeds for long periods (as high as 700 hours) on a series of dynamometer test stands equipped for accurate measurement of power output, engine speeds, and other variables. Four 250-hp. and two 400-hp. induction dynamometers are employed in the endurance testing of engine parts. Each dynamometer is equipped with a double Hagan "ThrusTorq" to measure left- or right-hand rotation force or torque. Along with other instruments, these are linked to the centrally-located control panels in the corridor outside the series of test cells, so that the operators can conveniently take readings and make throttle adjustments without entering.

4 REASONS FOR THE *Phenomenal Acceptance*

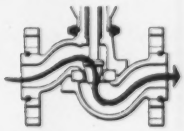
OF ANNIN DOMOTOR VALVES

IN SEVERE AUTOMATIC CONTROL SERVICE





1 **POSITIVE AUTOMATIC OPERATION.** Powerful Domotor unit with built-in valve positioner and sealed-in piston . . . replacing conventional spring and diaphragm with externally attached positioner . . . is not limited to lower operating pressures or short valve travel. Simple, practical design provides a stability and precision of operation not found in other control valves.



2 **PROVEN SINGLE SEAT VALVE BODY DESIGN.** Valve seat is clamped in position between separable body valves permitting a smooth, clean, non-turbulent flow passage that effectively handles slurries, sludges, and viscous fluids at high pressures and temperatures. Pressure drop is minimized. Unique construction allows economical manufacture in a wide range of alloys.

3 **DEPENDABLE SERVICE UNDER ADVERSE CONDITIONS.** Domotor assembly actuating the one-piece stem and valve plug within the simplified valve body provides the surest combination for dependable service. Development of the Annico Seat Seal permits use of Telfon and other wear-resistant seating surfaces to insure bubble-tight shut-off, even under the *most* corrosive conditions.

4 **LOW MAINTENANCE COSTS.** On the job, in the line, replacement of valve plug, ring seat and other vital parts is rapidly completed. Grinding-in operations are eliminated due to inherent seat alignment. Interchangeable line flanges permit use of one valve anywhere in plant regardless of line pressure, further reducing inventory and operating costs.

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Magnolia Petroleum Co.	The Dow Chemical Company
Pure Oil Co.	E. I. du Pont de Nemours & Co.
Shell Oil Co.	Ethyl Corporation
Sinclair Refining Co.	Jefferson Chemical
Standard Oil Co.	Mathieson Alkali
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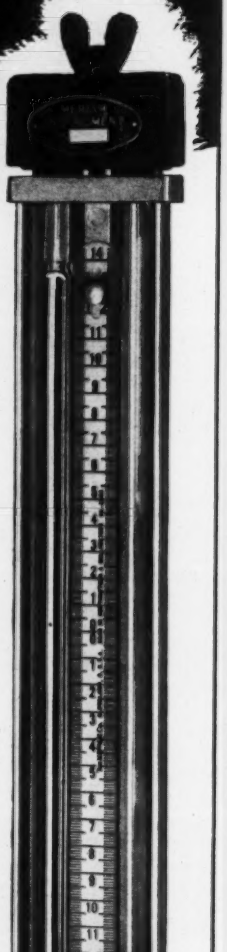

Measuring directly in inches or millimeters of mercury

This new instrument is proving notably popular in various industries for the measurement of *absolute pressures* from one millimeter of mercury to the equivalent atmospheric pressure.

It is a U-tube manometer with one leg sealed and filled with mercury; the other open tube leg connects to the source of pressure to be measured. The tube is removable and can be easily replaced, when necessary, with another tube, mercury filled, shipped directly to location.

Of simple design—no cams, gears, levers—the Meriam U-Type Absolute Pressure Gauge is accurate and dependable. It is strongly built for lasting service. The gauge head fastens to the body by a single wing nut. Available in wall or flush front mounting styles. The wall mounted unit, illustrated, is Model C-1142 WM and is fully described in catalog sheet C-1142 WM—available upon request.

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MERIAM *Instruments*
ESTABLISHED 1911

MANOMETERS, METERS AND GAUGES FOR THE ACCURATE MEASUREMENT OF PRESSURES, VACUUMS AND FLOWS OF LIQUIDS AND GASES

link, monitored by an operator at a central control station while the actual starting and stopping of the cameras are performed by an observer who is located at any strategic station.

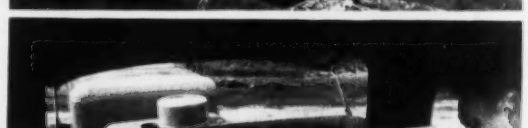
"Demodulated signals in the remote aircraft duplicate the control sequence in a smaller version of the parent installation. The remote unit has its own time base, synchronizing and control elements, and recording equipment. In addition to the control functions, 1-second timing marks are transmitted and appear on the records of both aircraft."

Features of the new system were summarized by the authors as follows:—

"(1) The camera control system described produced shutter synchronization within one aircraft to 0.002 second. (2) Phase difference between the cameras of two aircraft may exist but the difference can be determined from the oscillograph records. (3) The actual time of shutter openings may be determined for all cameras from the oscillograph records to 0.001 second of time. (4) The driving system is unique in that series d-c. motors running at 3600 rpm. are caused to operate synchronously by pulses from a 1200 rpm shaft, and camera shutters in one aircraft are locked-in for simultaneous frame-by-frame operation. (5) Provisions are made for operating 17 cameras in the parent aircraft and 5 cameras in the remote aircraft."

Rapid Method of Locating Defects in Oilfield Pipes, etc.

HOUSTON, TEX.—Based on the use of modern instruments, a rapid and economical method for the prevention of failure in drill pipe, tubing and casing has been announced. The "Sonoscope Method," as it is called, utilizes the induction of electromagnetic energy, in conjunction with controlled ultrasonic stressing, in the piece to be tested. Discontinuities and variations in structure are not only located but recorded on permanent graphs. No special preparation of the pipe is necessary.



This new instrumental method is a service performed by the Tuboscope Division of the Tubular Service and Engineering Co. The instruments are not for sale, only the service as shown in the typical photographs: the upper picture shows a detector unit being moved over a length of pipe; the lower picture—a view inside the Sonoscope truck—shows an operator logging discontinuities on the recording instrument. It shows also the control panel whereby the entire autographic instrumentation is kept in proper adjustment.

Improvement of Laboratory Gas Burners

WASHINGTON, D. C.—The flame characteristics of natural gas are so different from those of manufactured fuel gases that a change in gas supply from manufactured to natural gas necessitates the alteration of all gas-burning appliances. The different requirements of Bunsen and similar types of laboratory burners when they are used with natural gas have usually been overlooked by manufacturers. Even those burners advertised as designed for natural gas have not proved satisfactory.

As a result of this difficulty the National Bureau of Standards secured and tested sixteen different laboratory-type Bunsen burners, eight of which were of the Meker type and eight, straight tube burners. The limits of operation of each of these burners, sold as suitable for natural gas, were determined. By a correlation of these data with the basic requirements for good burner design, the reasons for the poor showing on natural gas and the changes required for satisfactory operation were found.*

A survey of the various heating operations for which a laboratory burner is used indicated that the Meker-type

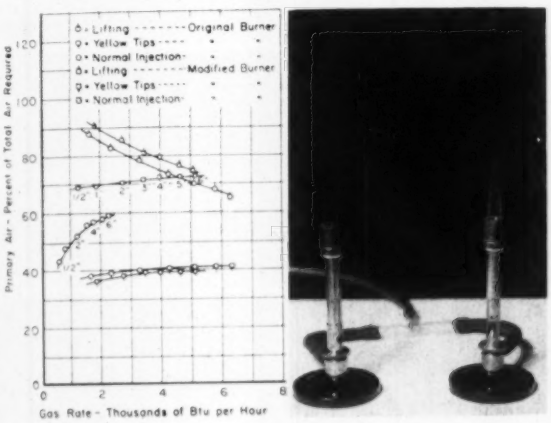

δ = Lifting ------- Original Burner
○ = Yellow Tips ----- " "
○ = Normal Injection " "
δ = Lifting ------- Modified Burner
○ = Yellow Tips ----- " "
○ = Normal Injection " "
Primary Air - Percent of Total Air Required
Gas Rate - Thousands of Btu per Hour

Fig. 1. Graph showing effect on normal operation of rebuilding the straight tube burner shown in Fig. 2. The operating characteristics of both the original burner and the modified burner are given in curves.

Fig. 2. Reasons for unsatisfactory performance were found to be too small a port area, improper throat size, and insufficient primary air opening. Two burners were modified so that they complied with theoretical requirements for good burner operation. The flame characteristics of one of these, a Bunsen type burner, are compared before and after alteration (left and right, respectively). Both burners are adjusted so that gas is being burned at the rate of 5,000 Btu. per hour.

burner should be capable of producing a hot, stable flame at gas rates up to 10,000 Btu. per hour, and the straight tube burners should be usable at rates up to 5000 Btu. per hour. The average maximum usable rate for the Meker burners tested was only 6363 Btu. per hour, while that for the straight tube burners was 2781 Btu. per hour.

A comparison of the dimensions of the sixteen burners with the fundamental relations for good burner operation brought out three major reasons for their unsatisfactory performance on natural gas.

(1) *Too small port area.* A Meker burner should have at least one square inch of free port area in order to deliver as much as 10,000 Btu. per hour; only two of the eight Meker burners examined had ports as large as one square inch. From the results obtained on the straight tube burners a port area of at least 0.15 square inch should be provided if rates up to 5000 Btu. per hour are desired. Only one of the straight tube burners had a port as large as 0.15 square inch.

(2) *Improper throat size.* Results both from this study and those conducted by other investigators show the need of a throat with an area equal to 40 percent of the port area if optimum air entrainment is to be obtained. Most

For further technical details see "A Study of Laboratory Bunsen Burners for Natural Gas," by John H. Eiseman, *National Bureau of Standards Journal of Research*, Vol. 42, 1949, page 541.

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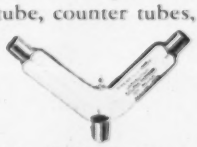
We're not in the standard vacuum tube business. But we are definitely in the business of developing and manufacturing special purpose vacuum tubes—tubes that are not generally available. During the past three years, for example, our facilities have produced, such devices as the Chronotron thermal time delay tube, the Convectron* vertical sensing tube, the TT-1 3000 mc temperature limited noise diode tube, counter tubes, glass enclosed spark gaps, and phono pickup tubes. Quantities of all these are now serving many phases of industry in a wide variety of applications. We invite your use of our facilities to develop and produce your requirements of special purpose vacuum tubes. Your inquiries concerning the scope of our facilities or details of any of our tubes will be given immediate attention.

TT-1 3000 mc Temperature Limited Noise Diode Tube.



Y-Type Position Convectron—Vertical Sensing Tube.

Chronotron Thermal Time Delay Tube.

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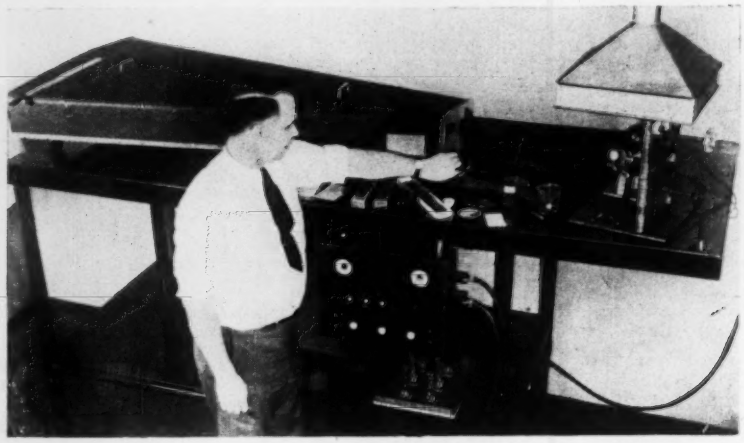


SPECTROGRAPHIC ANALYSIS FOR WATER CONDITIONING. The usual chemical method of analyzing boiler scales, deposits or other materials is time-consuming—a serious disadvantage. To supplement it with a faster technique, identification experts of Hall Laboratories, Inc., Pittsburgh, now are using the spectrograph in the solution of water problems—a relatively new application of spectrography. As a result, they can identify constituents of a deposit within hours or even minutes. In many cases the cause of a boiler tube failure may be ferreted out quickly without requiring days. The sample is burned in a d-c. arc which breaks down practically all compounds into their elements. Most of these produce a series of identifying lines, observed by eye or recorded on photographic film for later study. Photo shows spectrograph being operated by R. K. Scott, Chief of Identification Section of Hall Laboratories.

of the burners were unable to inject enough air to give a satisfactory flame with an orifice of adequate capacity. Only three of the Meker burners had throats close enough to the 40 percent requirement to approach optimum conditions.

(3) *Insufficient primary air opening.* Results showed a need for an air opening equal to at least 2.25 times the port area in order to insure sufficient primary air. A burner may be designed with a large enough port area and the proper Venturi throat to inject a high percentage of primary air but may be prevented from doing so because of too small an opening for the air to enter the mixing tube. Of the sixteen burners only five had a ratio of air-shutter opening to port area as large as 2.25.

In addition to these three factors, use of the proper orifice size is equally important. The orifice size should be such as to give the maximum desired gas rate when used in its wide-open position, and the needle should be used only to reduce the rate below this maximum.

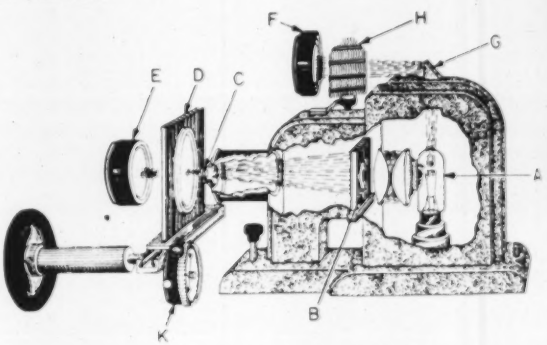
Fortunately, most of the changes required in these burners are not difficult to make. Two burners, one a straight tube and the other a Meker type, were modified in Bureau shops so that they complied with the requirements outlined above. These burners were then retested and found to be greatly improved. The Meker burner gave a hot, stable flame at all rates up to 10,000 Btu. per hour and the straight tube burner could be satisfactorily used at rates up to 5000 Btu. per hour. The modified Meker burner was also used for a number of laboratory heating applications which required intense heat, for example, sodium carbonate fusion. It performed all of these operations satisfactorily.

The results, together with a demonstration of redesigned burners, were presented recently to a group of interested manufacturers. As a result of this meeting several manufacturers are redesigning their burners. The improved appliances will be available in the near future.

A "Photomicrometer" for Measuring X-Ray Diffraction Patterns

WASHINGTON, D. C.—In a crystalline material such as metal, the interatomic spacing is altered by the application of an external stress. Since this spacing can be measured by x-ray diffraction techniques, it is possible to determine the magnitude of the lattice strain. In connection with investigations in the field of x-ray strain measurements, John A. Bennett of the National Bureau of Standards has developed a "photomicrometer" which has several advantages in measuring diffraction patterns. This work represents an extension of a previous development by the Bureau's Metallurgy Division of a more sensitive x-ray diffraction technique for the determination of strain in metals.

The primary difficulty encountered in the x-ray measurement of stress or strain in metals is the lack of sensitivity. This is due to the small change in diameter of the diffraction ring with change in stress and the diffuse nature of the ring, which makes precise measurement of its diameter difficult. The principal requirement of an instrument for measuring the diffraction rings is, therefore, a high degree of accuracy. The Knorr-Albers microphotometer was excellent in this regard, but it has two limitations: (1) its chart record is jagged, making it difficult to locate the maximum; (2) the time required to obtain measurements is excessive.



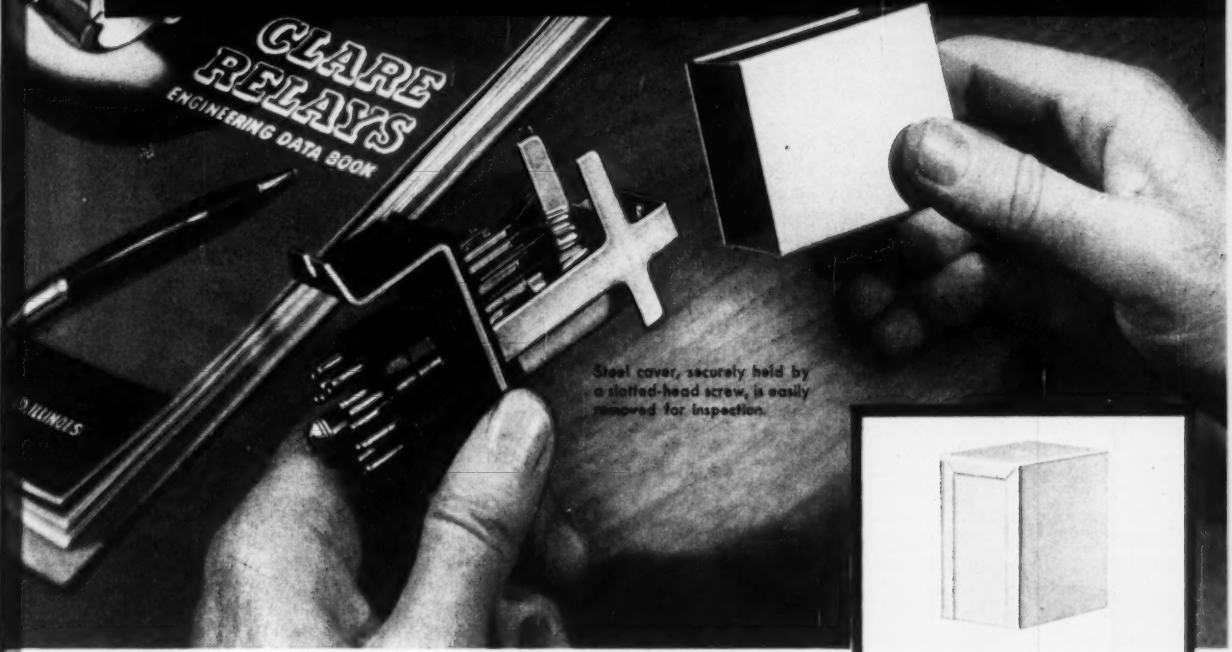
Schematic diagram showing the operation of the "Photomicrometer" developed at the National Bureau of Standards. Light from the source (A) is focussed by condenser lenses onto a curved slit (B). The image of the slit, reduced 5 to 1 by the 24-mm. microscope objective (C) is focussed on the film in the holder (D), and the light which passes through the film is measured by photocell (E). Variations in the intensity of the source are compensated by cell (F) which receives its light through a prism (G) and adjusting screen (H). Movement of the film holder is measured by the dial indicator (K).

In order to eliminate these disadvantages without decreasing the accuracy obtained on the microphotometer, the new instrument was designed for measuring the patterns directly. The calibrating ring of known inside diameter is recorded on the film immediately after the diffraction ring, and the radius of the diffraction ring is determined by measuring its distance from the inside of the calibrating ring. Use of the new instrument over a several month period has saved about 25 percent of the total time or 15 to 20 minutes per pattern.

Navigation Instruments Respond Like Human Mind

WASHINGTON, D. C.—New types of electronic systems which have the ability to store and recognize information in a manner similar to that of the human mind were revealed by Nathan Marchand and M. Leifer of the Physics Laboratories of Sylvania Electric Products Inc., at the meet-

CLARE TYPE "J" TWIN CONTACT RELAY



Steel cover, securely held by a slotted-head screw, is easily removed for inspection.

● This new CLARE dust-tight plug-in enclosure for the small Type "J" Relay offers designers a number of unusual features for installation on industrial equipment.

Entrance of dust is prevented by the steel cover and by use of a Neoprene gasket which is closely fitted at the factory to the relay terminals. The dust-tight cover is easily removed for inspection. Use of standard radio plug simplifies installation and cuts wiring costs. Base is secured to chassis to prevent plug from being jarred or accidentally pulled from its socket.

Exclusive design of the CLARE Type "J" Relay allows the twin contacts to operate independently of each other. One contact is sure to close, reducing contact failure to the practical limit. This relay combines all the best features of the conventional telephone-type relay with small size and light weight. It provides unusually high current-carrying capacity, large contact spring capacity, extreme sensitivity and high operating speed.

This new dust-tight enclosed relay is one of many outstanding CLARE contributions in the development of new and better relay components for industry. CLARE Sales Engineers are located in principal cities to consult with you on your relay problems. Call them direct or write: C. P. Clare & Co., 4719 West Sunnyside Avenue, Chicago 30, Illinois. Cable Address: CLARELAY. In Canada: Canadian Line Materials Ltd., Toronto 13.

Write for Bulletin No. 108

Neoprene gasket, closely fitted at factory to relay terminals, between base and cover, effectively occludes dust.

Plug is standard radio-type plug. Standard finishes are silver lustre lacquer for cover, cadmium for base. Retaining screws hold base securely to panel.

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Designed for incorporation on original equipment. This is the only counter made in which the entire case is a single casting . . . provides greater rigidity, tighter seal of working parts and new streamlined contour. This unit is compact and rugged, and features a flush mounted window to assure greater visibility of easy-to-read numerals.

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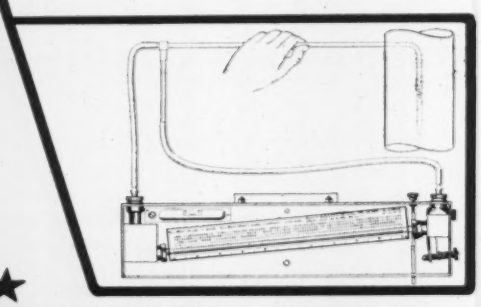

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ing of the International Radio Scientific Union in connection with the Institute of Radio Engineers.

A point of difference between human mental processes and the processes of the electronic mechanism, according to Marchand and Leifer, is that the latter responds at a much faster rate. This makes it particularly useful where rapid calculations are needed as in radar, sonar, and aircraft navigation.

Because of this feature, Marchand and Leifer said, electronic mechanisms in communications systems using periodic signals may be used to replace certain functions of human observers. The capacity of the human observer for receiving and correlating information with information previously stored in his mind is limited.

"We have made apparatus which is many times faster than the human being is able to receive and correlate information," they said. It operates through the use of a particular periodic signal which may be distinguished from all other signals by its characteristics. These distinctive characteristics include distribution of amplitudes, frequencies and phase of the modulation sidebands. Recognition of a particular signal with a high degree of certainty can be accomplished by correlating the received signal characteristic with that of a stored signal in the receiver.

When the electronic mechanism is applied in a spectrum analyzer it performs a Fourier analysis. The concept of orthogonality of signals as applied to periodic systems, according to Marchand and Leifer, emphasizes the use of complex signals for best correlation.

They also said that a practical example of the application of the new electronic mechanism is in radar where design parameters ordinarily depend on an operator. Using the electronic mechanism they showed how radar systems can be redesigned for greater use of information contained in reflected radar signals.

Automatic Speed-control Clutch

PROVIDENCE, R. I.—Development of a clutch-driven generator with an almost constant output, despite driving speeds, was described here before the North Eastern District Meeting of the American Institute of Electrical Engineers.

The clutch device, according to two engineers, has been developed by the Naval Ordnance Laboratory, Washington, D. C., and was recommended for use in fractional-horsepower equipment, and as an accurate voltage regulating device on d-c. generators driven from variable-speed shafts. It was also suggested for use in aircraft and automobiles as a constant-speed drive for pumps and fans.

Authors of the paper, G. G. Gould and E. Krupotich, said that the units are "completely self-contained, requiring no external excitation or reference frequency and are capable of limited frequency adjustment."

The centrifugally-governed magnetic-fluid clutch embodies "a mixture of fine iron powder and oil filling the space between two relatively moving ferrous drums. This magnetic fluid is made more or less viscous by a controllable magnetic field, whose excitation is obtained directly from the alternator through a small full-wave dry-disk rectifier. To insure alternator starting, even with no clutch exciting current, a small permanent magnet is mounted on the clutch output shaft to provide the requisite starting torque and to permit excitation build up as in ordinary d-c. generators. Automatic frequency control is obtained by regulating the amount of clutch current by use of a Lee type centrifugal governor in the clutch circuit.

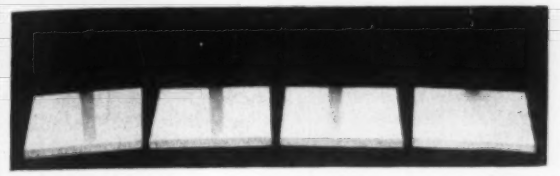
"At a predetermined speed, depending on the governor setting, the governor contacts tend to open by reason of centrifugal force; however, since this tends to reduce the control current and in turn the governor speed, the generator maintains constant speed for any further drive-speed increase. The regulating speed is chosen by pre-arrangement of a small backing screw on the governor so as to accommodate both normal increases and decreases in driving speed."

The authors said that the clutch-drive alternator will maintain its output frequency constant within one percent although driving speeds vary more than 80 percent.

Permanent Gloss Standards

WASHINGTON, D. C.—Permanent gloss standards, covering the entire gloss range of non-metallic commercial materials, are now available from the National Bureau of Standards. These standards, which may be used to calibrate any 60-degree specular glossmeter in the range from matte to high gloss, are made of ceramic materials for permanence, and the surfaces have been specially chosen for similarity to commercial materials whose gloss is important. Sets of the 60-degree specular gloss standards may be ordered from the National Bureau of Standards, Washington 25, D. C., for $70.00 a set.

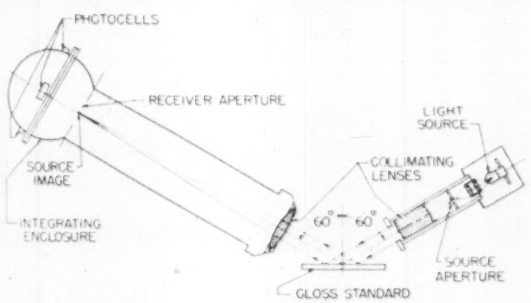
The gloss measurement is essentially a simple one. When a specimen is illuminated at some angle from the perpendicular, the proportion of the light reflected at angles near



These gloss standards illustrate specular gloss, the surface brightness decreasing from right to left. The distinctiveness of the images reflected from these gloss standards (nominal gloss: 90, 80, 40, and 1, left to right) shows a type of gloss related to specular gloss and more readily depicted photographically.

that of mirror reflection is defined as gloss. A critical part of the definition of gloss, however, is the amount that the reflected beam may depart from the strict direction of mirror reflection and still be counted as contributing to gloss. With glossmeters commercially available at the present time, replacement of the lamp, for example, may introduce instrumental error unless readjustment is made. The new gloss standards permit a rapid check of instrument calibration at any time and give a basis for readjustment of the instrument if required.

The gloss standards have been prepared according to ASTM Method D523 for the 60-degree Specular Gloss of Paint Finishes. A set consists of two white Vitrolite plaques



Schematic diagram of the NBS Glossmeter illustrating the procedure for calibrating the gloss standards issued by the National Bureau of Standards.

having nominal gloss values 1 and 90, and eight glazed ceramic plaques with nominal gloss values 10, 20, 30, 40, 50, 60, 70, and 80. Each plaque, approximately 4½ inches square, is engraved with the nominal gloss value followed by a serial number. The edges and backs of the ceramic plaques are coated with glyptal cement to prevent absorption of water.

Since glossiness is a surface reflection characteristic, the condition of the surface must remain unchanged if the reported gloss values are to remain valid. The surfaces of the standards have been found to be reasonably permanent, but they must be protected from dirt and abrasion.

Even with the aid of standards it is not possible to do precise gloss measurement in the medium to high gloss range unless the glossmeter used meets very closely the

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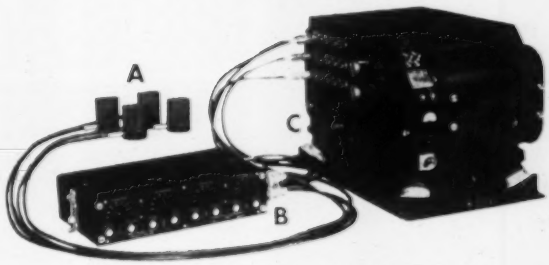

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The Matching Network, Type 8-201, is a precision four-channel unit, consisting of individual impedance-matching transformers and six-step attenuators for each channel. The case is designed for stacking with other Consolidated products and utilizes standard Cannon connectors.

For further information, send for Bulletin CEC-1517-X2.

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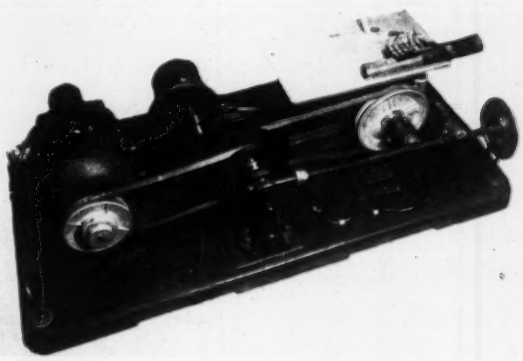
aperture requirements of ASTM Method D523, or unless the reflected light flux distribution of the specimen and standard are nearly identical. Since it is not practical to meet the latter requirement, it is desirable to make a test for the former. This may be accomplished by following simple instructions.

Rugged Electron-tube Development

WASHINGTON, D. C.—Rugged electron tubes are indispensable wherever electronic equipment is used under severe conditions of vibration, shock, or acceleration. Important in the development of such tubes are methods of testing for sturdiness and durability. These methods are now being studied and developed at the National Bureau of Standards as part of a comprehensive tube ruggedization program under the direction of I. L. Cherrick of the Bureau's Electron Tube Laboratory. One phase of the project consists of a survey of the actual operating conditions for electron tubes in various kinds of commercial, industrial, and military applications. This study provides a practical basis for the design of test equipment to simulate the hazards of actual use.

In addition to working out adequate test methods, the Bureau is developing new kinds of rugged tubes. The design of these tubes is based on an analysis of the ways in



Mechanical vibration machines are used in the Electron Tube Laboratory at the NBS to test the ability of electron tubes to withstand low-frequency vibrations. The vibrator shown here employs a cardioid cam to vary the vibration frequency through a continuous cycle in order to study the effects of different frequencies on tube performance. Tubes can be mounted directly on the vibrating table, or on extension arms to give larger vibration amplitudes.

which ordinary tubes fail under test or in service. A detailed knowledge of operating conditions and tube failures is thus a useful guide to the design of tubes that will be strong enough to operate properly under severe mechanical abuse. Some tubes may have to withstand great extremes of temperature as well, but in any case the mechanical design of a rugged tube is strictly governed by the required electrical properties.

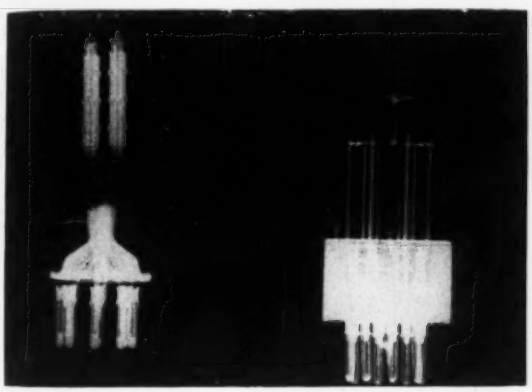
The Bureau's facilities for testing the ruggedness of electron tubes now include vibration apparatus, mechanical resonance testers, high-impact shock machines, and high-speed centrifuges. Some tests are conducted with typical electrical potentials applied to the tube elements so that noise modulation, short circuits, and other effects can easily be studied. Destructive field conditions can be reproduced through the proper choice of vibration, resonance, impact, and acceleration tests.

After receiving various ruggedness tests, tubes are examined for structural failures. X-rays are sometimes used to reveal the extent of structural changes without opening the tube envelope. Materials for certain tube elements are examined spectroscopically to determine their exact composition and to find impurities that might weaken the tube structure. This determination of the real causes of tube failure is an important part of the rugged tube program. Out of these studies will come recommended specifications for materials best suited to particular ruggedization prob-

lems. In some cases new materials and new methods of fabrication must be developed to meet the unusual requirements of ruggedization.

Mechanical Resonance Tests.—The most severe effects are encountered in cases where the vibration applied to the tube contains components of a particular frequency which corresponds to the natural frequency of vibration of some tube element or structure. The electrical noise in the output of the tube will then have a sharp peak at this resonant frequency which may be large enough to completely override the desired signal. Microphonic effects are a major problem in applications where the normal mechanical vibration occurs over such a broad frequency spectrum that the natural resonant frequency of a particular tube element is excited by some component of the incident vibrational energy.

The mechanical resonance testers in use at the Bureau are in the form of loud-speaker-type vibrators. The vibrator is excited by means of an audio oscillator and amplifier which produce an a-f. signal that can be varied from low frequencies up to more than 20,000 cps. This vibration is monitored by means of a magnetic-type moving-coil vibration pickup attached to the tube mounting. The proper electrode potentials are furnished by a battery power supply to minimize extraneous noise effects. In testing for microphonism a special mounting is used to transmit the vibrational energy directly to the tube, and a cathode-ray oscilloscope is connected to the plate circuit of the tube so that noise modulation corresponding to a given mechanical vibration frequency will appear as a deflection on the oscilloscope screen.



Radiograph of two type 6SN7GT electron tubes shows the internal structure of a regular nonruggedized tube at left and a ruggedized version at right. The x-ray photograph illustrates the essential structural superiority of ruggedized tubes. Compare the heavy, rigid arrangement at right with the narrow, weak design at left. The radiograph was made at a distance of 32 inches with an exposure of 6 seconds at 120 kilovolts peak and 10 milliamperes, no intensifying screen, 1 millimeter aluminum filter.

At certain critical frequencies noticeable resonances may occur in any tube. The vibration of the plate itself may be sufficient to produce an objectionable noise effect. In some cases the mechanical resonance vibration may be sufficient to cause fatigue failure of tube elements. For example, oxide coatings of cathodes will often flake off as a result of resonance vibrations. The best preventive for resonance conditions is to design the tube so that the natural resonant frequencies of the various tube elements are higher than the vibration frequencies met in practice. It is important to use stiff materials for structural parts, to shorten the tube structure, and to design the cross sections of elements for greatest rigidity.

In general, mechanical resonance can be reduced by isolating the tubes from sources of low and high frequency vibration by means of rubber mountings of suitable design and by making the tube structure as rigid as possible to avoid resonance with high-frequency vibrations. It is extremely important to employ low-strain designs at all points of glass-to-metal contact and to eliminate brittle materials wherever possible. It is often useful to carry out a

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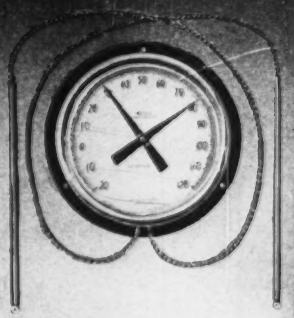

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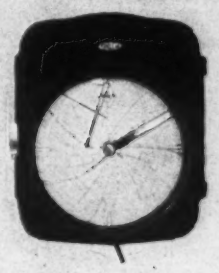

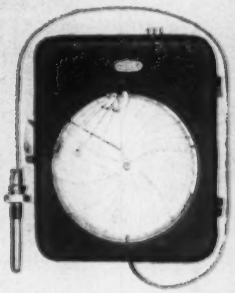

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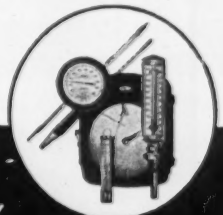

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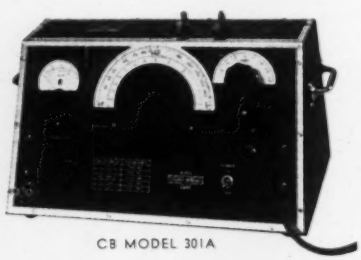

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theoretical analysis for an idealized structure approximating the structure of the tube under consideration. In this way, the designer can achieve a rough guide to the resonant frequencies of each tube element and an indication of whether or not a proposed design will be satisfactory.

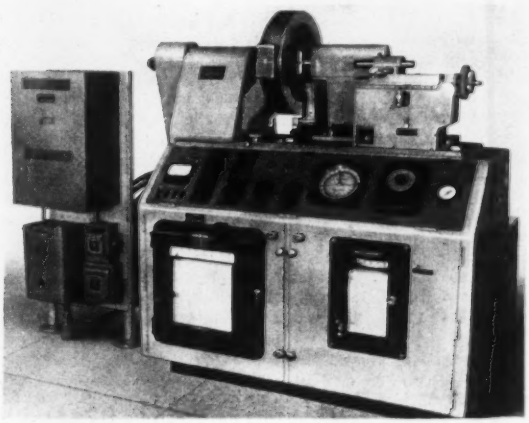
Testing and Design.—The development of rugged electron tubes is a good example of the interdependence of testing and design. In a sense, the creation of rugged tubes is brought about through a series of successive approximations. The development of a rugged tube might begin by applying appropriate mechanical tests to an existing commercial type whose electrical characteristics suit the intended application. The results of these tests would show in what way this tube type fails to meet the ruggedness requirements. A preliminary revision of the tube design could then be made with the test results as a guide, and a handmade model constructed in the model shop. The same tests could then be repeated for this experimental tube. Usually the tube would turn out to be a vast improvement over the commercial type, but in some respects it might not yet fulfill the necessary ruggedness requirements. At this point the designer would probably have a clear idea of the direction to take in order to achieve a satisfactory rugged tube. It might involve a search for better materials for use in some tube elements, new methods of fabrication adapted to eventual mass production, or better geometrical configurations and alignment of tube elements for maximum rigidity. The influence of each structural element on the over-all strength of the tube would be carefully considered. Thus, through a succession of several trial designs a suitable rugged tube would be evolved.

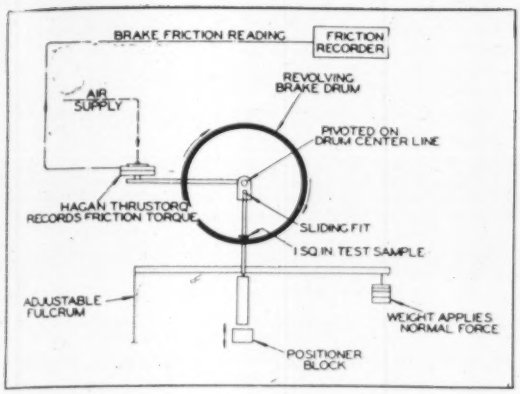
At present the cost of rugged tubes is about three or four times more than conventional tubes. But it is not unreasonable to expect that as more is learned about production methods and materials applicable to rugged tube types the cost will be much less and all preferred tube types will eventually be available in ruggedized form.

New Brake-lining Tester

TROY, N. Y.—Bendix research men have "brought the highway into the laboratory" with a new machine that accurately tests brake linings in hours, where formerly the work took days or even weeks. A task force of engineers at the Bendix Research Laboratories, Detroit, developed the new machine for the Marshall Eclipse Division of Bendix, in accordance with the basic ideas of David Bonawit, Division Chief Engineer. Initial tests of the machine have been completed, and it has been moved to Troy for service. It will enable the brake-lining researchers to test a far greater variety and volume of material compounds, than ever before, so that over-the-road testing work can be concentrated on brake linings that have shown promise in the laboratory.

The Bendix Research Division had to overcome a major design difficulty that frustrated earlier efforts in the auto-





motive industry to develop such a machine. This is the tendency of the brake-lining sample when tested on a revolving brake drum to move out of position, affecting the applied load and destroying the accuracy of test results. To overcome this, the Bendix research men built into their machine a unique system for holding the sample in place without interfering with the load. The brake lining sample is held by an adapter (itself constituting part of the dead load on the sample). The adapter is linked, through a torque arm and a shim stock fulcrum pivoted on a needle bearing, to the flexible diaphragm of a Hagan "ThrusTorq." This last is a pneumatic force-measuring device which responds automatically to load on the diaphragm by using compressed air pressure to keep diaphragm in position. The diaphragm actuates a relay valve that regulates the admittance or exhausting of the air. Thus the diaphragm and—through its linkage with it, the brake-lining sample—remain in position, and the air pressure utilized to perform this key function is a direct measure of the torque developed by the brake-lining sample.

Safe Handling of Radioactive Isotopes

WASHINGTON, D.C.—Recommendations for the safe handling of artificially-produced radioactive isotopes in the typical laboratory or small industrial operation are concisely set forth in Handbook H 42, *Safe Handling of Radioactive Isotopes*, just issued by the National Bureau of Standards and now available from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. Price, 15 cents. Remittances from foreign countries should be in United States exchange and should include an additional sum of one-third the publication price to cover the cost of mailing.

Survey-type Magnetometer

SCHENECTADY, N. Y.—Hunting sunken ships and surveying vast areas for iron deposits from aircraft are among the possible peace-time uses of a device developed here by Dr. Albert W. Hull, assistant director of the General Electric Research Laboratory.

Dr. Hull has received a patent, his 91st. on a modification of a magnetometer, an instrument sensitive to slight variations in the earth's magnetic field, such as those caused by iron deposits in the ground, or by large metallic objects, such as sunken ships. A plane equipped with the improved magnetometer could conceivably explore large areas for iron deposits, simply by flying back and forth over them, according to Dr. Hull. Because the need for so accurate an instrument is extremely limited, the device will not be made commercially available at the present time, the company said.

The instrument consists of a detecting coil, which produces a current proportional to the strength of the earth's magnetic field, and equipment for measuring variations in the current so produced. As the magnetometer-equipped plane moves through the earth's field, changes in the cur-

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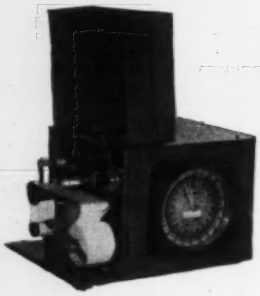

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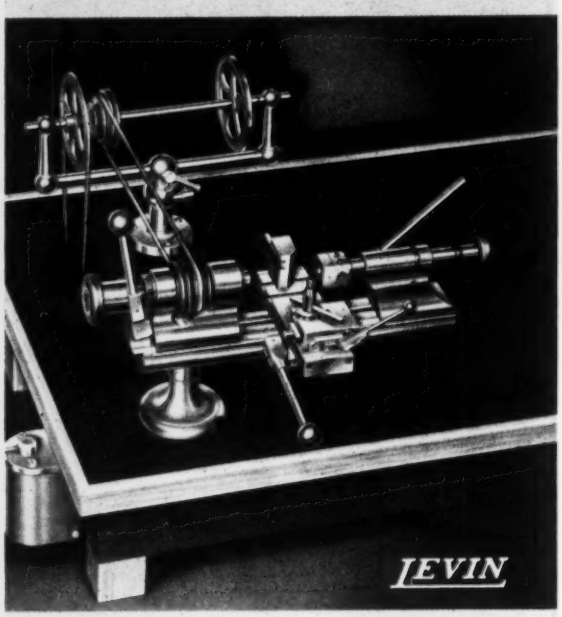

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rent flowing from the coil are indications that metal or iron minerals are distorting the field at that point, provided that the detecting coil has been kept in a constant position relative to the field, Dr. Hull explained.

His invention has to do with means, including a gyroscope, for holding the axis of the detector coil parallel to the earth's field. An arrangement in the device controls the position of a gyroscope rotor, which, in turn, keeps the detecting coil in alignment with the earth's field. If the coil departs from the proper position, a compensating current is set up immediately to correct the measurements taken.

Dual Automatic Motor Speed Control and Speed Proportioning System

PATERSON, N. J.—Many industrial requirements arise for the speed control of fractional horsepower motors, not only under an operator's control as with standard motor speed control systems, but also in direct proportion to other variables. In those applications the speed variation or control must be automatic and a function of such variables as: (a) position, (b) tension, (c) speed of rotation of a master unit which is variable, (d) rate of linear travel of some material, (e) rate of fluid flow, and many others.

Such automatic speed control methods simplify factory

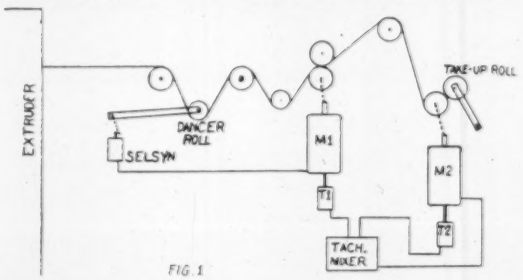


FIG. 1

manufacturing procedures in varied industries including textiles, plastics, chemicals, etc., according to Oscar E. Carlson, of Servo-Tek Products Co.

Mr. Carlson cited a representative control problem as an illustrative example of methods applicable to many industries and processes:

"A motor whose speed was to be controlled as a function of position of angular rotation of lever arm assembly on a dancer roll was also to be synchronized with a second 'spooling' motor at prescribed and selectable percentages of the speed of the first motor.

"Since the dancer roll lever arm was to have a maximum angular movement of plus or/and minus 6 degrees, extreme sensitivity of control was required. The spooling motor which was to operate at proportional synchronism with that first motor must hold that synchronism over wide ranges of load requirements.

"A basic block diagram of the new control system is shown in Fig. 1 for these functional requirements. Two identical d-c. amplifier-controlled full-wave thyratron power rectifier motor power units were utilized. The dancer-roll-actuated unit which required d-c. voltage input proportional to angular position was connected to the rectified output of a small Selsyn, shaft-mounted at lever pivot point. The rectified output of its stator winding provided a change of voltage of 0.1 volts per degree of angular shaft rotation. Since the motor control amplifier is capable of changing motor speed from 0 rpm. to 1800 rpm. with a voltage input change of 0.3 volts or less, it is seen that a plus or minus 50 percent speed variation around a mean of 900 rpm. can be achieved by an angular rotation of plus and minus 1.5 degree, or a total angular spread of 3 degrees. Suitable sensitivity control allows for selecting the required angular change for the specific installation and conditions involved.

"A d-c. tachometer generator is coupled to that motor shaft and its output voltage bucked against a second tach-

ometer generator signal coupled to the shaft of the second or spooling motor.

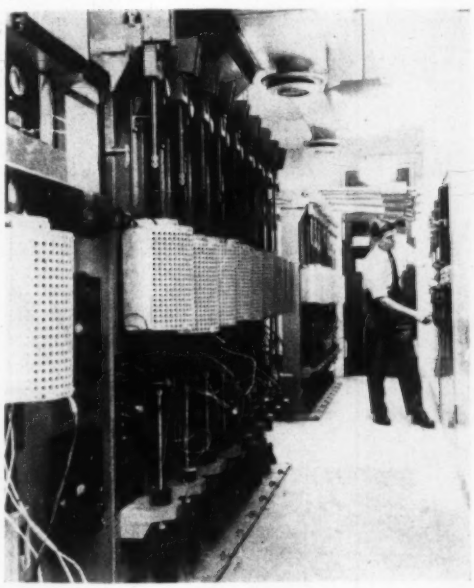
"With a tachometer output voltage of 2 volts per 100 rpm. it is readily apparent that with 0.3 volts needed for zero to full-speed variation, nearly perfect speed regulation versus lead is achieved in the second or tachometer controlled motor. This of course allows for nearly perfect holding of the synchronizing ratio."

Establishment and Maintenance of the Electrical Units

WASHINGTON, D. C.—A description of the new system of electrical measurement using "absolute" units, adopted by the International Conference of Weights and Measures and officially instituted January 1, 1948, is described in a new booklet, Circular C475, *Establishment and Maintenance of the Electrical Units*, by F. B. Silsbee, published by the National Bureau of Standards and available from the U. S. Government Printing Office.

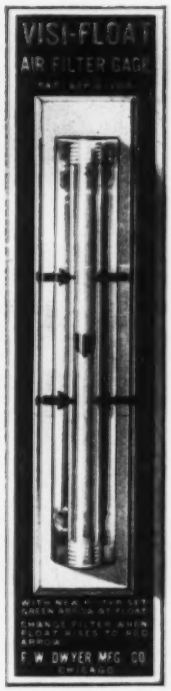
This is a booklet of 38 large double-column pages, illustrated with 23 diagrams, half-tones, and tables; available (25 cents a copy) from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.

Remittances from foreign countries must be made in United States exchange and must include an additional sum of one-third the publication price to cover mailing costs.



Battery of 20 creep-testing machines of the most modern type, recently put in operation at the Research Laboratory of National Tube Co., in Pittsburgh, as part of the expansion program for research and production equipment now in progress throughout United States Steel Corp. subsidiaries. The machines have been installed in a compact bank, complete with an auxiliary power supply, constant primary voltage control and complete instrumentation. The unit includes 18 lever-type machines and 2 screw-driven machines.

Furnace temperatures are automatically controlled within plus or minus two degrees Fahr. Records are obtained from three 6-point recorders which operate in conjunction with the controllers. The fact that the machines and instruments all operate in an air-conditioned room maintained at a constant temperature of 79° F. is of great help in maintaining consistent records as the problem of control is greatly simplified. Without the air conditioning, variations in room temperature from 50 to 75° F. would require compensation, involving constant adjustments of the instruments and control equipment.



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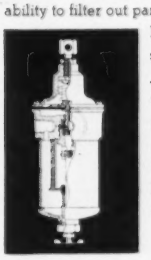

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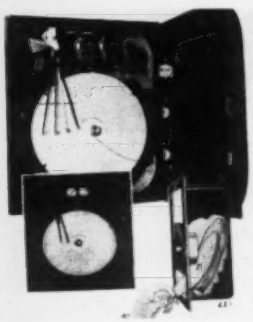
The Month's NEW INSTRUMENTS

In this department we report each month new devices for measurement. inspection, testing. metering and automatic control — in the form of concise technical descriptions.

FOR FURTHER INFORMATION USE THE POSTAGE-FREE ORDER CARD ON PAGE 523

Pressure and Temperature Recorders

New and amplified line of pressure and temperature recorders is announced. Temperature-measurement systems of gas-filled, vapor-tension and liquid-filled types for ranges from —100 F. to 800 F. are offered. Bourdon springs are said to be unusually sturdy. Emphasis is also placed on accurate

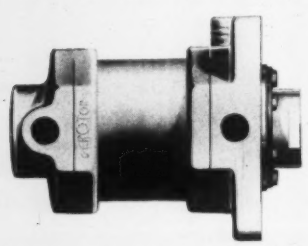


calibration and long aging of each element. New case design accommodates up to four pens (any combination of temperature and pressure). Storage space within case for 200 charts and 4 bottles of ink: operators can perform routine functions of chart-changing and pen-filling with no chance of applying wrong chart. Hence cost savings to large user and much greater convenience to small user.—*Penn Industrial Instrument Corp.*, 3116 *N. 17th St., Philadelphia 32, Pa.*

Mention No. 501 when filling out card.

Hydraulic Power Units

New "Gerotor" hydraulic cylinders have an extra-large piston rod, permitting retraction at twice the speed of extension. Cylinders are available in



ten bore diameters, in any length stroke up to 96 in., and with cushioning at either or both ends of piston rod. Mountings available are: rod-end flange, foot, trunnion, center-line, blind-end flange, and clevis.—*Rivett Lathe & Grinder, Inc., Brighton 35, Boston, Mass.*

Mention No. 502 when filling out card.

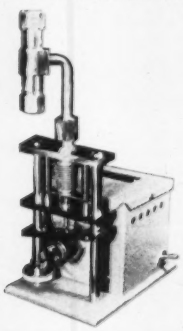
Miniature Radiation Pyrometer Receiver

New miniature "Radiamatic" radiation pyrometer receiver unit, for flame hardening and induction heat treating, is for use where space is limited, and in ranges from 200 to 2500 F. It is said to measure temperatures of targets as small as one-half-inch diameter, at a distance of six inches. Deliveries of the new model will be made about June 1.—*Brown Instruments Div., Minneapolis-Honeywell Regulator Co., Wayne and Roberts Avenues, Philadelphia 44, Penna.*

Menton No. 503 when filling out card.

Metering Pump

New "Type C" metering pump is of pulsation type, using a bellows, fittings, and check, all of stainless steel. Pumping rate is 15-1000 cc. per hour with a



0.5 in. bellows, and 30-2000 cc. per hour with a 0.75 in. bellows. Connections are for eighth-inch pipe. 30 rpm. motor runs 110 v., 60 cps. Weight is 5.6 lb.—*Research Appliance Co., Box 413 West View Rd., Pittsburgh 9, Pa.*

Mention No. 504 when filling out card.

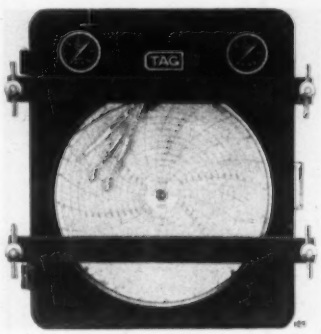
Photoelectric Light Recorder

New photoelectric light recorder consists of a "Photronic" photocell assembly and a "Celectray" self-balancing potentiometer-circuit ten-inch strip-chart recorder, so arranged and calibrated that full-chart deflection can be obtained with 20, 40 or 80 foot-candles of illumination on photocell. Range is selected by selector switch on box containing photocell and its attenuating circuit. Records are of illumination as seen by human eye: conforming to ICI Luminosity Curve. Recorder pen can traverse full chart width in ten seconds and rapid changes are recorded without overshooting.—*Weston Electrical Instrument Corp., Newark 5, N. J.*

Mention No. 505 when filling out card.

Humidity Recorder-controller

New "Tagliabue" recorder-controller for humidity utilizes psychrometric wet and dry-bulb principle, where controller automatically regulates wet-bulb (relative-humidity) depression for which it is set, regardless of any fluctuations in dry-bulb temperature. Two



pens operate on a circular 10-in. chart, simultaneously recording dry-bulb temperature and wet-bulb depression. Flow of humidifying agent, moisture, steam, or oil fog is regulated by a valve which is operated by control instrument. For applications involving gas, such as saturation of natural gas in mains, bars can be clamped on case of instrument to make it gas tight.—*Weston Electrical Instrument Corp., 614 Frelinghuysen Ave., Newark 5, N. J.*

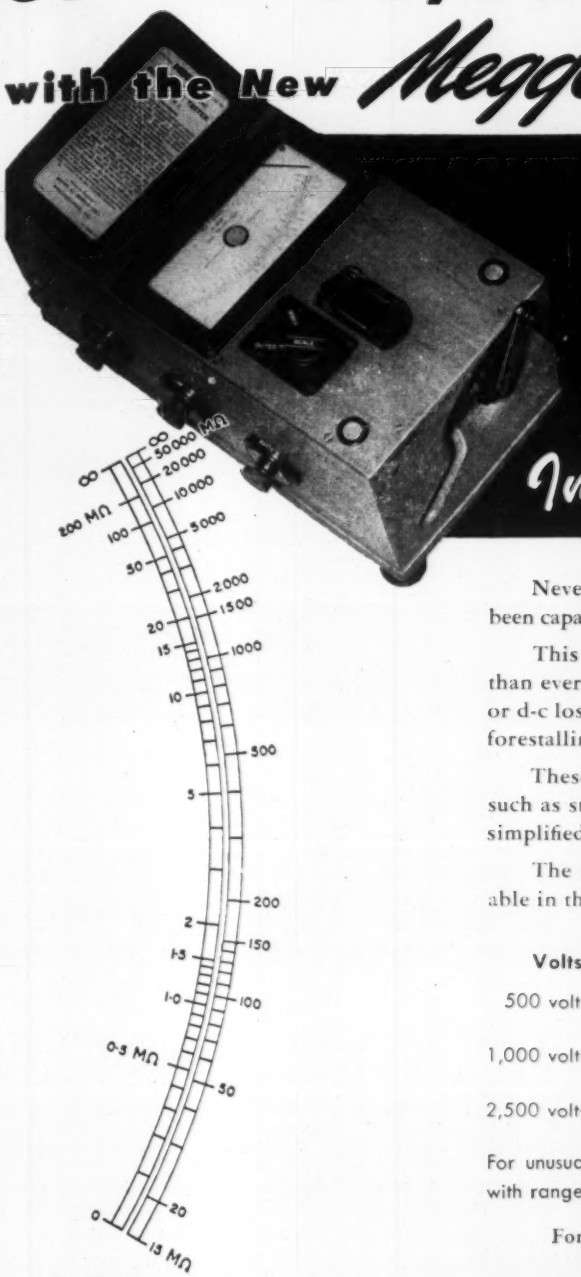
Mention No. 506 when filling out card.

Reader-analyzer for Oscillogram

New "Type 25-105" analyzer for oscillographic records up to 12 in. wide may be used with a companion instrument to record up to 50 data points per minute on IBM cards. Instrument provides digital coordinate readings of any selected data point on chart. Viewing screen is 15 by 30 in. Chart speed is

UP TO 50,000 MEGOHMS

with the New *Megger*® Insulation Tester



Facsimile scale of 2,500-volt instrument

New **Higher ranges**
Wider ranges
Longer scales
Improved **Mechanical Features**

Never before has the direct-indicating cross-coil ohmmeter been capable of measuring such high values of insulation resistance!

This accomplishment comes at a time when more attention than ever is being focused by engineers on insulation resistance or d-c loss measurements as a practical non-destructive means of forestalling breakdown in electrical equipment.

These new sets also include several important improvements, such as static shielding, improved hand-drive mechanism, and a simplified design for motor-drive with better voltage stabilization.

The new line of MEGGER Insulation Testers is now available in the following ranges:

Volts	Inner Scale Megohms	Outer Scale Megohms
500 volts d-c	0 to 50	3 to 10,000
1,000 volts d-c	0 to 100	6 to 20,000
2,500 volts d-c	0 to 200	15 to 50,000

For unusual requirements, a special 5,000-volt instrument is available with range up to 100,000 megohms.

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controlled by foot pedal from 0.5 to 1200 in. per minute.—*Consolidated Engineering Corp., 620 No. Lake Ave., Pasadena 4, Calif.*

Mention No. 507 when filling out card.

Industrial Television System

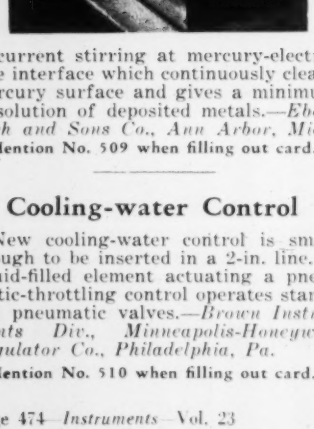
New "Model ITV-1" industrial television system uses a miniature camera employing standard 16mm. movie lenses, a receiver with a 7-in. viewing

screen, and operates from 110-v. 60-cps. current with a consumption of 375 watts. Scanning is 525-lines, 60-frames, interlaced. Scene-brightness needed is 2 foot-lamberts minimum. Controls are similar to usual TV practice.—*Engineering Products Dep't, Radio Corp. of America, Camden, N. J.*

Mention No. 508 when filling out card.

Polarographic-method Analyzer

New "Dyna-Cath" polarographic analyzer uses mercury cathode with a magnetic circuit which causes coun-



tercurrent stirring at mercury-electrolyte interface which continuously cleans mercury surface and gives a minimum re-solution of deposited metals.—*Eberbach and Sons Co., Ann Arbor, Mich.*

Mention No. 509 when filling out card.

Cooling-water Control

New cooling-water control is small enough to be inserted in a 2-in. line. A liquid-filled element actuating a pneumatic-throttling control operates standard pneumatic valves.—*Brown Instruments Div., Minneapolis-Honeywell Regulator Co., Philadelphia, Pa.*

Mention No. 510 when filling out card.

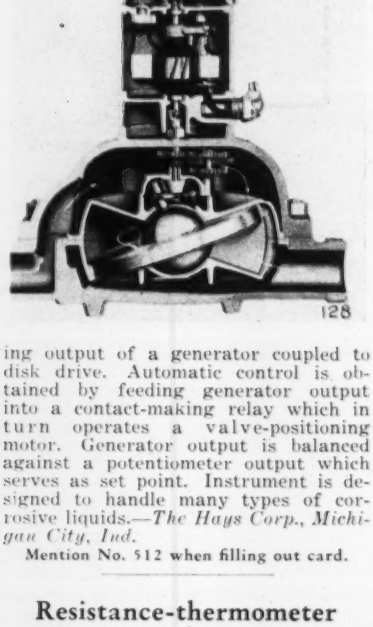
Ball-point Pen for Recorders

New accessory for maker's line of strip-chart recorders is a ball-point pen for use where measurements demand rapid pen movement. Pen characteristics prevent smudging where lines are close together.—*Brown Instruments Div., Minneapolis-Honeywell Regulator Co., Philadelphia, Pa.*

Mention No. 511 when filling out card.

Flow Integrator-controller

New "Veriflow and Veritrol" flowmeters and -controllers utilize the nutating-disk principle to obtain volumetric measurement of flow. Integration is obtained from a gear train coupling disk drive to a set of counting wheels. Flow indication is obtained by measur-



ing output of a generator coupled to disk drive. Automatic control is obtained by feeding generator output into a contact-making relay which in turn operates a valve-positioning motor. Generator output is balanced against a potentiometer output which serves as set point. Instrument is designed to handle many types of corrosive liquids.—*The Hays Corp., Michigan City, Ind.*

Mention No. 512 when filling out card.

Resistance-thermometer Element for Air Ducts

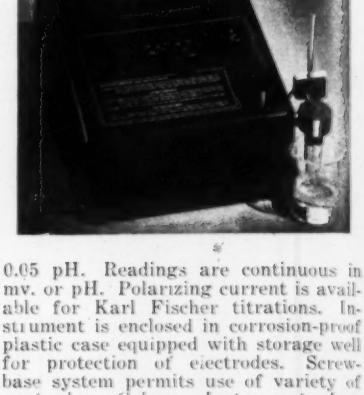
New resistance thermometer is pressure-tight and fitted with standard AN connectors. Spring contact be-

tween element and well, separated by mica insulation, is said to give response approaching that of bare wire.—*Barber-Colman Co., Rockford, Ill.*

Mention No. 513 when filling out card.

Line-operated pH Meter

New "Model 30" pH meter operates from 95-130 v. 60 cps. with almost complete freedom from drifting. Accuracy and reproducibility is within



0.05 pH. Readings are continuous in mv. or pH. Polarizing current is available for Karl Fischer titrations. Instrument is enclosed in corrosion-proof plastic case equipped with storage well for protection of electrodes. Screw-base system permits use of variety of electrodes.—*Coleman Instruments, Inc., 318 Madison St., Maywood, Ill.*

Mention No. 514 when filling out card.

Pressure Telemetering System

New pressure telemetering system with 50,000-lb. pressure range and 30-mile range has been developed jointly by Manning, Maxwell & Moore Co. and undersigned. System consists of "Microsen" transmitter and "ElectroniK" indicating or recording instrument. Multi-point recorders can be employed with a number of transmitters.—*Brown Instruments Div., Minneapolis-Honeywell Reg. Co., Wayne and Roberts Aves., Philadelphia 44, Pa.*

Mention No. 515 when filling out card.

Decade Inductors

New decade inductors, available in single-decade units for building into other equipment and in three- and four-decade cabinet assemblies for laboratory use, provide precise decade steps of inductance from one millihenry to one henry per step. Cores are molybdenum permalloy dust toroids with precisely-adjusted, banked windings. Temperature coefficient of inductance is -24 parts per million per degree C. over normal range of room temperatures, and maximum storage factor,

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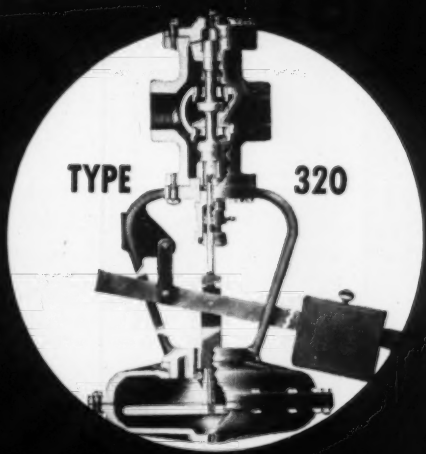
Type 320 Regulators allow sensitive pressure control in vapor-vacuum and low-pressure steam heating systems. Weight loaded, pressure operated, diaphragm actuated. Built for long life under rugged conditions.



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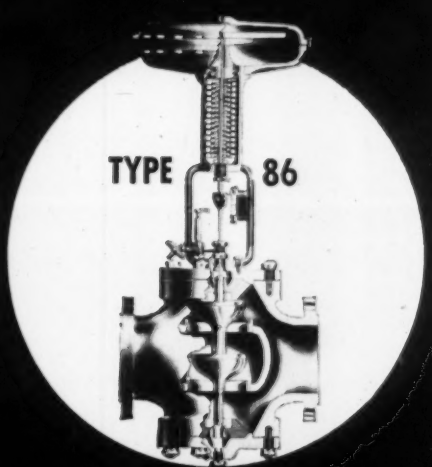
Type 86...famous the world over for high lift, accurate control, ease of maintenance. Fully reversible in the field. Super polished lower stem for minimum friction. Wide rangeability. Check coupon for catalog.



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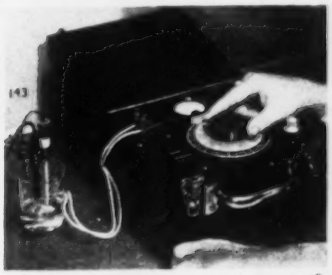
No leakage...no stuffing box...no friction problem! That's the Type 850, a BS&B-Climax-developed exclusive. Ideal wherever liquid level control involves exacting and wide range control. Shown here with Type 1410 BS&B-Climax Control Pilot. Complete catalog available...send coupon now.

Q, is between 200 and 330. Accuracies range from 2 percent for the one-millihenry steps to 0.25 percent for the one-henry steps.—*General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass.*

Mention No. 516 when filling out card.

Portable Potentiometer

New "Model P-2" portable potentiometer is designed for making potential measurements of high-impedance electrochemical cells or electronic tubes



and circuits. Three ranges cover potentials from 0 to 3 v., with current flow in measured circuit of less than ten million-millionths amp. Standard cell is built in. Accuracy is to one tenth percent.—*Southwestern Industrial Electronic Co., 2831 Post Oak Rd., Houston 19, Texas.*

Mention No. 517 when filling out card.

Nepho-colorimeter

New "Model 9" nepho-colorimeter gives colorimetric readings either by direct deflection of taut-suspension galvanometer or by calibrated potentiometer with null indication. For nephel-

ometry, where suspensions are too dilute to measure accurately by transmitted light, measurement and evaluation of haze in liquids by dispersed (Tyndall) light is performed.—*Cascade Instruments, Inc.,—318 Madison St., Maywood, Ill.*

Menton No. 518 when filling out card.

Automatic Viscosimeter

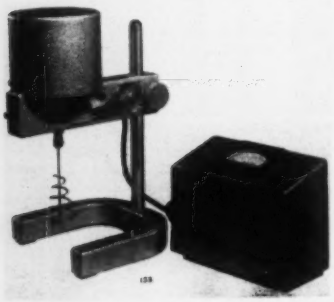
New "Electroviscometer" reads viscosity directly in centipoise units in the ranges 0-500 and 500-5000 using two bobbins. Unit includes constant-temperature bath, and magnet-cooling

fan. Principle of operation is to revolve sample in a cup at a constant speed around a bobbin. Magnetic force applied to counteract fluid-shearing force on bobbin is a measure of viscosity and is calibrated as such on indicator.—*Fisher Scientific Co.*, 717 *Forbes St.*, *Pittsburgh* 19, *Pa.*

Mention No. 519 when filling out card.

Automatic Viscosimeter

New viscosimeter can be used with any potentiometric recording device. Automatic stop is provided at maximum deflection. Additional outlet for

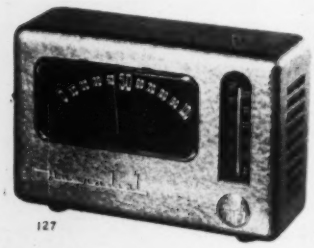


intermittent timer is available for studies of congealing substances. Instrument is adaptable to laboratory or continuous-plant operation.—*Emil Greiner Co.*, 20-26 *N. Moore St.*, *New York*, *N. Y.*

Mention No. 520 when filling out card.

Humidity-temperature Indicator

New source of supply for "Hygrodial" humidity-temperature indicator



described in our Dec. 1949 issue, page 1108, is the *Abbeon Supply Co.*, 58-10 41*st Dr.*, *Woodside*, *N. Y.*

Mention No. 521 when filling out card.

Time-delay Valve

New time-delay valve operates by volume measurement of air which assures constant repetition of time sequence when a regulated supply is used. Unit is available in sizes from

0.25 to 1.25 in. in straightway, 3-way, n-o. and n-c. models. Valve is especially adaptable to jigs, fixtures, and machine tools requiring a time sequence of two or more operations.—*Ross Operating Valve Co.*, 120 *E. Golden Gate Ave.*, *Detroit* 3, *Mich.*

Mention No. 522 when filling out card.

Pressure-actuated Switch

New model of "Visco-Trol" switch, believed first of its kind offered, is designed to be operated by heavy liquids and powders in explosive atmospheres; may be adjusted to actuate a s-p.d-t.

switching element at any predetermined pressure. Six classes of switches provide adjustable ranges from 2 in. of water to 100 psi. with proof pressures up to 120 psi. Over-all length 6 in. Pressure connection through 2-in. internal pipe thread. Electrical connection through ½ in. conduit connector. —*Meletron Corp.*, 950 *N. Highland Ave.*, *Los Angeles* 38, *Calif.*

Mention No. 523 when filling out card.

Miniature Seismograph Instruments

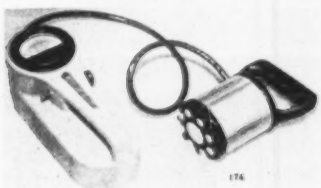
New "Type PSU-11" seismograph unit is designed around maker's "GA-11 Amplifier." Waterproof amplifier case pictured measures 6 x 13 x 21 in., weighs approx. 35 lbs., and contains twelve "GA-11" amplifiers plus control unit. Amplifier Specifications: Gain,

120 db (1,000,000), no pre-amplifiers necessary; filtering, 2 section *LC* filter for low-frequency rejection, 1 section *LC* filter for high-frequency rejection; AGC, operates over wide range to prevent distortion from high input levels; initial suppression, individually adjustable; amplifier controls, gain control, amplitude control, suppression control, and filter selectors. Amplifiers are plug-in type, and no soldering is necessary to replace them in the field. Oscillograph specifications: 25 traces; 6 in. paper; barrel type electromagnetically damped galvanometers; viewing screen; built-in timing system; built-in paper knife; removable take-up magazine; governor controlled cranking motor. Complete unit measures 8 x 9 x 16 in., weighs approx. 25 lbs.—*Southwestern Industrial Electronic Co.*, 2831 *Post Oak Road*, *P. O. Box* 13058, *Houston*, 19, *Texas.*

Mention No. 524 when filling out card.

Moisture Tester

New "Model RF 4" moisture tester has a range of 0-25 percent using spring-backed flat electrodes instead of conventional needles. Unit tests to a depth of 2 in. wood or more. One dial



is read and values taken from a calibration booklet listing 80 varieties of wood. Direct-reading dial for specific type of wood can be furnished. Readings are made in 3 sec. Total weight is 7 lb.—*Moisture Register Co.*, 133 *N. Garfield Ave.*, *Alhambra*, *Calif.*

Mention No. 525 when filling out card.

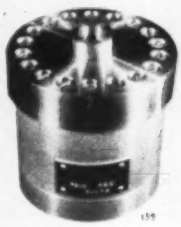
Batch Scale

New "Model No. 1745 Detecto-Gram" batch scale is made with a triple-beam assembly, provided with a polished-aluminum over-and-under head, and finished in white enamel. Over and underweight indicator speeds up weighing operations. Capacity is 200 lb., sensitive and measurable to 1 oz.—*Detecto Scales Inc.*, 540 *Park Ave.*, *Brooklyn* 5, *N. Y.*

Mention No. 526 when filling out card.

Pressure Transmitter

New "Teledyne" pressure transmitter for use with corrosive mediums employs four 300-ohm strain gages in a Wheatstone-bridge circuit which, with an input of 18 v., produces 50 mv. full

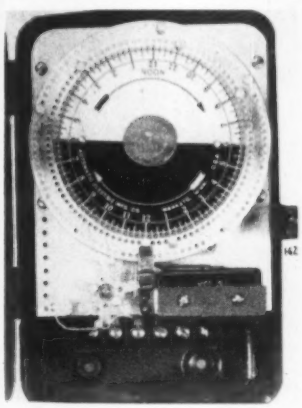


scale on open circuit. Output is linear with pressure, and repeatability is better than 0.25 percent of full scale. Zero shift is less than 0.01 percent full scale per degree F. with same stability for sensitivity. Ranges are from 100 to 5000 psi. Resonant frequency is over 1500 cps. depending on range.—*Fredric Flader, Inc., 583 Division St., N. Tonawanda N. Y.*

Mention No. 527 when filling out card.

48-operation Time Switch

New "Series 70 and 80 Cycle-Master" time switches are set by insertion of screw pins in programming dial. Intervals may be 15 minutes or more on 24-hour cycle, 7.5 on 12-hour, and 37.5

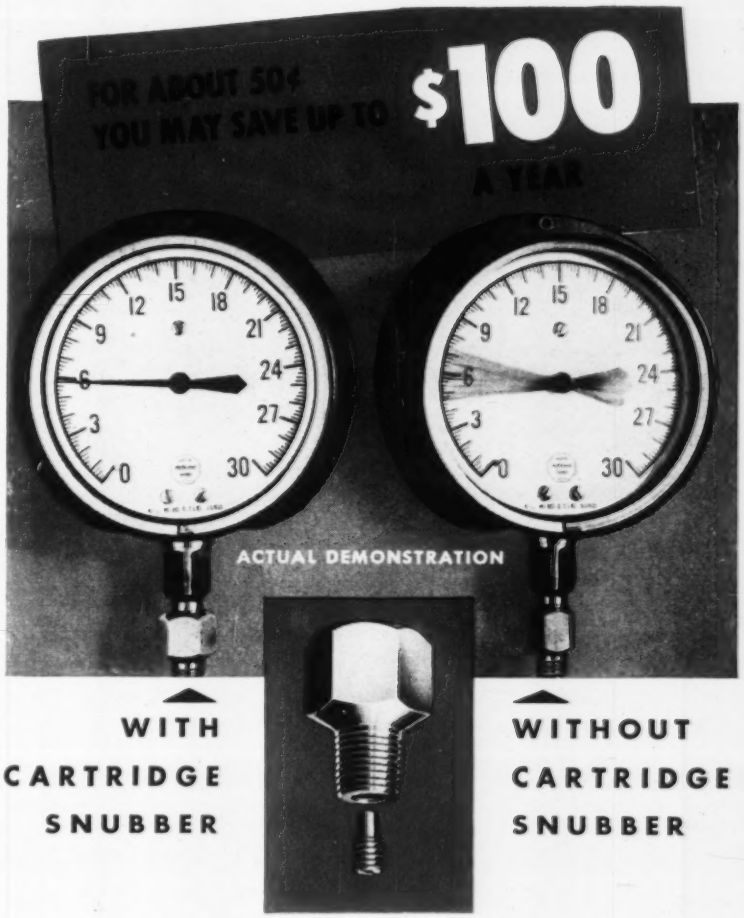


sec. on 1-hour cycle. First series has capacity of 10 and second of 20 amps. Either are available in s-p.s-t. through d-p.d-t. Sunday and holiday cutouts may be used.—*Automatic Electric Mfg. Co., Mankato, Minn.*

Mention No. 528 when filling out card.

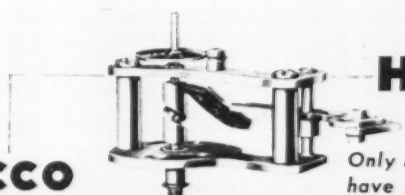
Recording Counter

New high-speed recording counter uses Teledeltos paper to give a record of position of 24 styli (four for each decade) to record a 6-digit number. Maker's 1-2-4-8 decimal designation for each digit is used. Illustration shows recorder attached to 1.6 Mc. counter-chronograph which will measure and record time intervals with an accuracy of 0.625 microsecond at repetition rates



● Why wreck gages needlessly? When pressure pulsations are so rapid that the gage pointer vibrates excessively, a HELICOID Cartridge Snubber is needed. This is the most simple and effective of all pressure pulsation dampeners. It is threaded into the gage socket for only 54¢. It may save you up to $100.00 a year in gage replacement expense!

For severe pulsation services, order your Helicoid gages with snubber cartridges in the socket. Or, order complete snubbers separately. Specify for water, air or oil; ¼" or ½"; bronze or stainless steel.



HELICOID

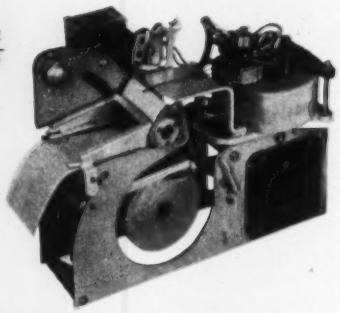
Only Helicoid Pressure Gages have the Helicoid Movement

ACCO

TRADE MARK

HELICOID GAGE DIVISION
AMERICAN CHAIN & CABLE COMPANY, INC.
Bridgeport 2, Connecticut

DIRECT WRITING RECORDERS



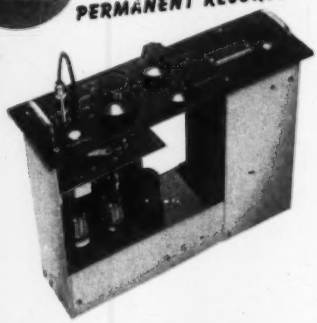
Records are produced by a heated writing stylus in contact with heat sensitive paper. The paper is pulled over a sharp edge in the paper drive mechanism (standard speed 25 mm/sec., slower available) and the stylus wipes along this edge as it swings, thus producing records in *true rectangular coordinates*. The writing arm is driven by a D'Arsonval moving coil Galvanometer with an extremely high torque movement (200,000 dyne cms per cm deflection).

This recorder assembly may be obtained in bare chassis form, as illustrated (51-600) with or without built-in timer; or, with the addition of a stylus heating transformer, temperature controls, and control panel (127); or, with the entire assembly, controls and control panel enclosed in a mahogany carrying case (127C). Complete catalog available, see below.

SINGLE CHANNEL

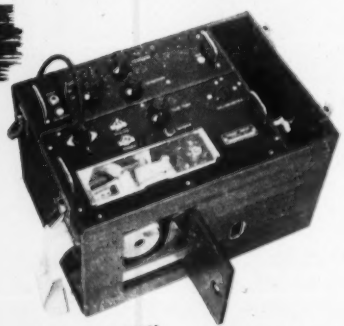
NO INK
RECTANGULAR COORDINATES
PERMANENT RECORDS

INSTRUMENT AMPLIFIERS



A general purpose, A.C. operated driver amplifier for use with model 127 Recorder, comprising three direct coupled push-pull stages. Maximum sensitivity 50 mv. per cm., minimum sensitivity 50 volts per cm., with four intermediate ranges. Balanced input terminals available with impedances of 5 megohms to ground. Complete information in catalog shown below.

AMPLIFIER-RECORDERS



Model shown at right is a single channel unit comprising above Amplifier 126 and Recorder 127, contained in one mahogany carrying case, and designed for use in the industrial field as a direct writing vacuum tube recording voltmeter capable of reproducing any electrical phenomena from the order of a few millivolts to more than 200 volts. More complete data in catalog shown below.

At lower right is a typical "Poly-Viso" multiple channel direct writing Recorder and Amplifier in console. Numerous combinations of this recording equipment and associated amplifiers and accessories are available. The Multi-channel Recorder (Model 165) provides for the simultaneous registration of *up to four* input phenomena, using the same principles and method as for the Recorder Assembly above. In addition, the "Poly-Viso" Recorder provides a selection of eight paper speeds: 50, 25, 10, 5, 2.5, 1.0, 0.5 and 0.25 mm/sec., and for the use of 4, 2, or 1 channel recording Permapaper. The Amplifier equipment is housed in a rack which has space for four individual driver amplifiers (electrically identical to model 126, above) and one 4-channel preamplifier.

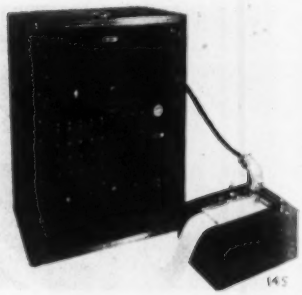
MULTI-CHANNEL

NO INK
RECTANGULAR COORDINATES
PERMANENT RECORDS

For complete catalog giving tables of constants, sizes and weights, illustrations, general description, and prices, address:

SANBORN COMPANY
Industrial Division
CAMBRIDGE 39, MASS.

Sanborn Recorders and Amplifiers have evolved from those originally designed by Sanborn Company for use in electrocardiographs, and have, by actual practice, proven to have wide applications in the industrial field as well.



up to 25 per second.—*Potter Instrument Co., Inc., 136-56 Roosevelt Ave., Flushing, N. Y.*

Mention No. 529 when filling out card.

Bore Gage

New line of six dial bore gages covers range of 0.625 to 12 in. with indicator in graduations of 0.0001 in. supplied as standard. Same indicator can be used with complete range, or any other type graduation of American

gage-design standard class can be substituted. Extensions can be interchanged quickly to check any diameter within range of gage. Gage employs three-point alignment and two-point gaging. Wear on contact point can be compensated for by adjustment on dial. —*Nilsson Gage Co., Inc., 2-A Lake St., Poughkeepsie, N. Y.*

Mention No. 530 when filling out card.

Fluorinating Cell

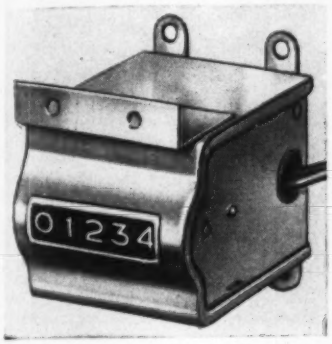
New model of fluorinating cell operates from any ungrounded d-c. supply capable of supplying 10 to 12 v. at 75 amp. Also required is a supply of 115 v., a.c. or d.c. at 750 watts to

heat water jacket. Product is nearly 0.7 grams Flourine per amp.-hour. Addition of HF is necessary only once per day. Water-jacket temperature is automatically controlled to range of 95 to 105 F.—*Harshaw Scientific Div. of Harshaw Chemical Co., 1945 E. 97th St., Cleveland 6, Ohio.*

Mention No. 531 when filling out card.

Electric Counter

New model of "Mercury" small electric counter mounts flush on panels, is enclosed in a tamper-proof metal case with plastic window. Non-resetable,

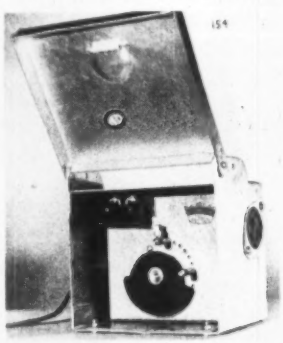


counts to 99,999 and repeats. Tested at 600 counts per minute. Furnished for 6, 24, 30, 115 and 230 v. 60-cy. a.c. and for 6, 24, 30 and 115 v. d.c. Over-all dimensions: 2.37 x 1.75 x 2.25 in.—*Production Instrument Co., 702 W. Jackson Blvd., Chicago 6, Ill.*

Mention No. 532 when filling out card.

Automatic Timer

New quick-change variable timer may be set to any cycle from 15 sec. on and 1 sec. off, to 1 sec. on, and 15 sec. off, with total cycle time ranging



from 2 to 16 sec. Loads up to 400-watts non-inductive a.c. can be handled. Switch is rated for over two million operations.—*Gale Davathea Mechanisms, Jackson Heights, Long Island, N. Y.*

Mention No. 533 when filling out card.

Snap Gage

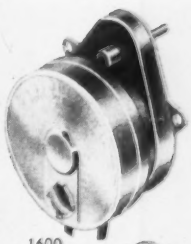
New dial snap gage features a framework machined from rolled magnesium with angles at 45 degrees to provide maximum rigidity and to minimize dimensional changes caused by tem-

Timing Ideas

WHEN TIMING
COUNTS

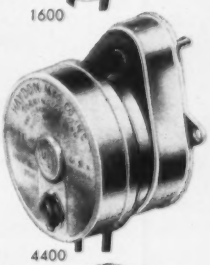
You can always count on Haydon to provide the right motor for your timing job. Timing Headquarters offers a broad line of efficient, economical timing motors and timers produced by specialists who have no other interest than to provide the best in timing.

LOW COST VERSATILITY—1600 SERIES:
Specifically designed as a standard component for the widest possible range of timing applications with 79 speeds from 300 rpm to 1 revolution per 4 hours.



1600

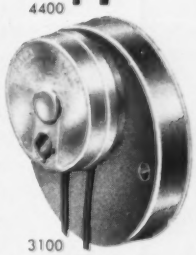
COMPACTNESS AND SLOW SPEED—4400 SERIES:
Designed for small size and low cost in applications requiring slower speeds from 6 hours to 7 days per revolution.



4400

HEAVY DUTY DEPENDABILITY—3100 SERIES:
For control and instrument applications that require a heavy duty train and speeds from 1 hour to 14 days per revolution.

SUPERIORITY FEATURES
Slow (450 rpm) rotor speed makes for quiet operation and long life. Unusually small. All motors totally enclosed. Separate rotor and reduction gearing lubricating systems permit selection of best methods and lubricants, control circulation, insure against leakage. Operates continuously in any position. Simple to mount, entire face of motor can be supported securely against mounting surface. Standard, interchangeable design in only 2 motor series with speed range from 300 rpm to 1 revolution in 7 days.



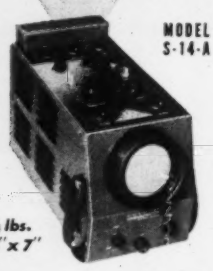
3100

For complete design and engineering specifications, write for catalog: Timing Motors No. 322 — Timers No. 323 — Clock Movements No. 324. Yours without obligation.

HAYDON AT TORRINGTON
HEADQUARTERS FOR TIMING

HAYDON Manufacturing Co., Inc.
2029 ELM STREET
TORRINGTON, CONNECTICUT
SUBSIDIARY OF GENERAL TIME CORPORATION

THE
HI-GAIN Industrial
POCKETSCOPE
BY WATERMAN



MODEL
S-14-A

Wt. 12 ¾ lbs.
12"x 5¾"x 7"

Another Waterman POCKETSCOPE providing the optimum in oscilloscope flexibility for analyses of low-level electrical impulses. Identified by its hi-sensitivity and incredible portability, S-14-A POCKETSCOPE now permits "on-the-spot" control, calibration and investigation of industrial electronic, medical and communications equipment. Direct coupling without peaking, used in the identical vertical and horizontal amplifiers, eliminates undesirable phase shifting. Designed for the engineer and constructed for rough handling, the HI-GAIN POCKETSCOPE serves as an invaluable precision tool for its owner.

Vertical and horizontal channels: 10mv rms/inch, with response within —2DB from DC to 200KC and pulse rise of 1.8μs. Non-frequency discriminating attenuators and gain controls with internal calibration of trace amplitude. Repetitive or trigger time base, with linearization from ½cps to 50KC with ± sync. or trigger. Trace expansion. Filter graph screen. Mu metal shield. And a host of other features.

WATERMAN PRODUCTS CO., INC.
PHILADELPHIA 25, PA.
CABLE ADDRESS: POKETSCOPE

WATERMAN PRODUCTS INCLUDE:

S-10-B GENERAL POCKETSCOPE
S-11-A INDUSTRIAL POCKETSCOPE
S-14-B WIDE-BAND POCKETSCOPE
S-15-A TWIN TUBE POCKETSCOPE
S-21-A LINEAR TIME BASE

Also RAKSCOPES, LINEAR AMPLIFIERS, RAYONIC® TUBES and other equipment

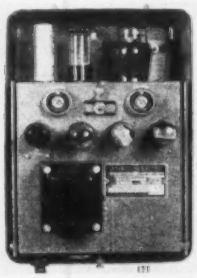
WATERMAN PRODUCTS

perature fluctuations. Gage also features a vernier-type screw which permits 0.25-in. adjustments in gaging pin or movable anvil. Adjustment can be locked with gaging pin remaining free for checking—*Nilsson Gage Co., Inc., 2-A Lake St., Poughkeepsie, N. Y.*

Mention No. 534 when filling out card.

Cut-off Register Controls

New line of one-way cut-off register controls for printed matter utilizes a thyratron-output tube for machine timing, or a VT output where an electronic



timer is used. Panels include voltage regulator tubes and have built-in light-source power supplies.—*General Electric Co., Schenectady 5, N. Y.*

Mention No. 535 when filling out card.

Aircraft Navigation Range Simulator

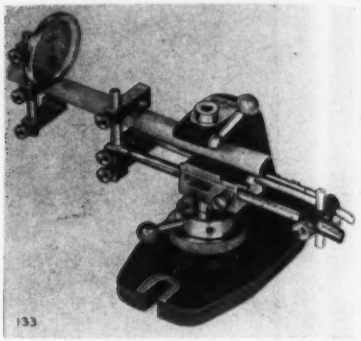
New "Model T-3" simulator for Omni-range navigation equipment generates all signal components of Omni station and Omni track, permitting

calibration tests to be made without removing receiving equipment from aircraft. Unit also produces signals necessary for testing phase-localizer approach equipment and for tone localizer and VAR equipment.—*National Aeronautical Corp., Wings Field, Ambler, Pa.*

Mention No. 536 when filling out card.

Universal Drilling Tool

New "Regulus" universal drilling tool of Swiss manufacture holds workpieces up to 1.75 in. dia., and accommodates drill bushings up to 0.468 in.

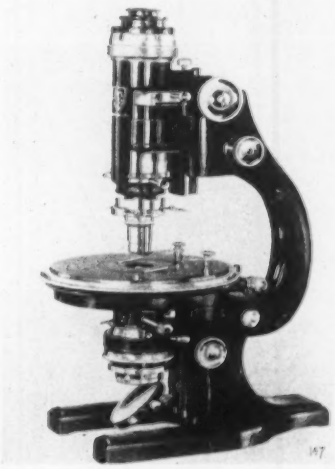


dia. Accessories include vee mount for cylinders, cone mount for balls, and a modified mount for flat and eccentric pieces. Instrument also serves as an angle comparator, a depth gage, and a center-distance comparator.—*Cosa Corp., 405 Lexington Ave., New York 17, N. Y.*

Mention No. 537 when filling out card.

Polarizing Microscopes

New polarizing microscopes utilize Polaroid optical elements in place of conventional calcite with price savings of about one-third. New elements have



been extensively used for past five years, and are now available in 12 new models as well as 8 lower-priced types.—*Instrument Div., American Optical Co., Buffalo, N. Y.*

Mention No. 538 when filling out card.

Automatic Bearing Ball-and-race Matcher

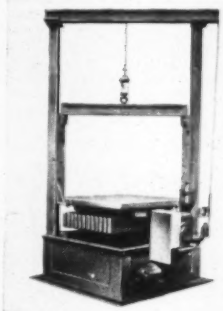
New "Selectionaire" matcher for races and balls automatically classifies and matches races and balls with an air-operated apparatus before assembly

of bearings so that accumulation of classification errors is avoided. Instrument may be pre-set to any desired tolerances.—*The Sheffield Corp., Dayton* 1, *Ohio.*

Mention No. 539 when filling out card.

Shock-testing Machine

New "Type 150 VD" impact-shock machine will handle equipment up to 36 by 36 by 30 in. weighing up to 150 lb. Steel-sheathed blocks, attached to

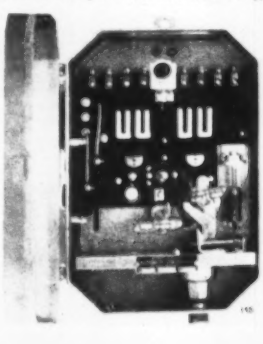


under side of platform, penetrate sand at end of drop to give a single deceleration pulse without rebound. Decelerations up to 100 G. can be obtained with durations between 6 and 32 milliseconds.—*The Barry Corp., 173 Sidney St., Cambridge* 39, *Mass.*

Mention No. 540 when filling out card.

Pump Protecting Control

New control prevents damage to pumps caused by running without discharging water; automatically stops pump, and keeps it from starting until



DRY COMPRESSED AIR FOR INSTRUMENTS ...to low dew points

Here's how KEMP Dynamic Dryers protect instruments, control moisture in instrument air at Low Cost!

COMPACT, inexpensive, standardized — that's the story behind Kemp Oriad *instrument* air dryers. Designed specifically for instruments, these dryers limit moisture content in instrument air to safe dew points! Operation is *uninterrupted*. One single lever changes flow and reactivation is accomplished automatically. Oriad Dryers are available in standard drying cycles.

DESIGNED FOR INSTRUMENTS

Kemp Dynamic Dryers are versatile—offer *manual, semi-automatic* or *automatic* operation. Drying to any *dew point you specify* is guaranteed, at an extremely low cost! Desiccant is selected especially for instrument work to provide effective moisture control. Choose gas, electric or steam regeneration as standard equipment.

SEND FOR INFORMATION

Whether your moisture control problem is special or standard, you'll find Kemp has a Dynamic Dryer especially designed to solve it. Find out how Kemp engineering can save you money. Get the facts on Kemp Dynamic Dryers. Bulletin D-27, contains specifications, technical data and full information. For free copy, mail coupon today!

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METAL MELTING UNITS
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THE C. M. KEMP MFG. CO., Dept. J-5
405 E. Oliver St., Baltimore 2, Md.

Gentlemen: Please send me Information Bulletin D-27. We want facts on drying ( ) air ( ) gas ( ) liquids.

Name .....
Company .....
Address .....
City ..... Zone ..... State .....

Elapsed time intervals can be measured down to 1/1000th second with a

STANDARD PRECISION TIMER

The world's most accurate (and rugged) time measuring instrument. Available in 8 models as shown below:

MODEL	READS	TOTALIZES	ACCURACY
S-100	1/5 sec.	6000 sec.	± .1 sec.
S-60	1/5 sec.	60 min.	± .1 sec.
SM-60	1/100 min.	60 min.	± .002 min.
S-10	1/10 sec.	1000 sec.	± .02 sec.
S-6	1/1000 min.	10 min.	± .0002 min.
S-1	1/100 sec.	60 sec.	± .01 sec.
MST	1/1000 sec.	.360 sec.	± .001 sec.
MST-500	1/1000 sec.	30 sec.	± .002 sec.

Manually and Electrically Operated Portable Cases or Panel Mounting optional changes to conform to customers' requirements.

Special Timing Problem. **Our engineers are ready to consult with you, and design timers to meet special timing problems.**

OTHER PRODUCTS

Standard Chrono-Tachometers, Custom-built Laboratory Test and Distribution Panels, School Time Program Systems, Hospital Doctor Paging and Nurse Call Systems.

WRITE FOR BULLETIN NO. 153

STANDARD

THE STANDARD ELECTRIC TIME CO.

93 LOGAN STREET **SPRINGFIELD, MASSACHUSETTS**

manually reset. Emergency condition causes audible alarm and warning light. Unit is equipped with alarm silencer and automatic reset. Pushing manual-reset button restores all circuits to regular operation.—*Automatic Control Co., St. Paul 4, Minn.*

Mention No. 541 when filling out card.

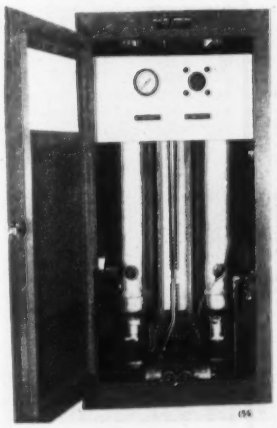
Atmosphere Sampler

New "Samplair" is essentially a pump which draws 600 cc. per stroke of handle of gas through filter-paper disks which collect acid mists for determination of concentration. Comparison with established color standards indicates concentrations which may be determined in range 0.5 to 4.0 mg. per 10 cubic meters.—*Mine Safety Appliances Co., Braddock, Thomas, and Meade Sts., Pittsburgh 8, Pa.*

Mention No. 542 when filling out card.

Air Dehumidifiers

New "Models 25 and 50 EIAC" air dehumidifiers will dry 25 and 50 cfm. air respectively at 100 psi. and 70 F. to a maximum dewpoint of minus 40 F.



Units operate from 110-v. 60-cps. line and are completely automatic. Cabinet dimensions are 22 by 18 by 43 in. with all piping and electrical connections terminating at bottom and back of cabinet.—*Industrial Corp., 88-35 76th Ave., Glendale, Brooklyn 27, N. Y.*

Mention No. 543 when filling out card.

Electrostatic Phasing Equipment

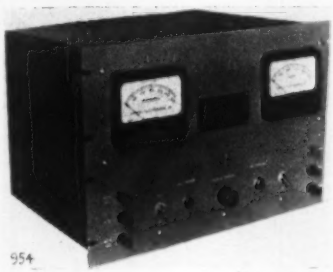
New "Models 1 and 2" electrostatic phasing equipment comprise two of maker's high-voltage indicators, with addition of an intermediate electrostatic voltmeter mounted on one stick, with a connecting lead running to other stick. Each stick is provided with a

heavy lead for connection to ground. Testing probes are applied to two lines to be compared. Reading on intermediate electrostatic voltmeter will show a difference in potential or phase between lines. First model is for systems up to 11 kv. and second for systems up to 33 kv.—*Ferranti Electric, Inc., 30 Rockefeller Plaza, New York, N. Y.*

Mention No. 544 when filling out card.

Regulated Power Supply

New "Model PSR-100" regulated power supply delivers 0 to 500 v. d.c., continuously variable, regulated within 0.5 percent for any line-voltage variation from 105 to 125 v. 60 cps. Ripple



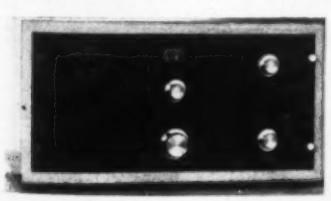
954

is less than 10 mv.; load current 0 to 300 ma.; impedance, effectively zero at any frequency; weight, 145 lb. Also supplied is an output of 6.3 v. 60 cps. at 6 amp., unregulated.—*American Electroneering Co., 2112 S. LaBrea Ave., Los Angeles 16, Calif.*

Mention No. 545 when filling out card.

Ultra-low-frequency Oscillator

New "Model 410-A" ultra-low-frequency oscillator provides both sine and square-wave outputs over frequency range from 0.02 to 20,000 cps. Six frequency bands are provided, each covering a full decade, with continuous control of frequency. A single 11-in. illuminated direct-reading logarithmic scale is used on all bands. Unit is useful for design and test of servomechanisms, control instruments and feed-

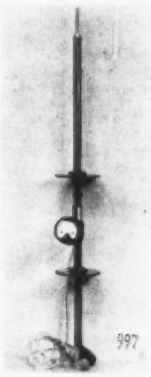


back amplifiers, and other purposes. Sine-wave output recovers to 90 percent of its steady-state amplitude in less than 2 cycles of dial frequency.—*Krohn-Hite Instrument Co., 580 Massachusetts Ave., Cambridge 39, Mass.*

Mention No. 546 when filling out card.

Electrostatic Kilovoltmeter

New "Models 1 and 2" kilovoltmeters are designed for instantaneous measurement of voltage to ground up to 20 kv. on live lines. Earthed end of stick is held in hand; other end applied to line to be tested. A reading of volt-



997

age to ground is given by electrostatic voltmeter mounted on stick, and connected through a capacitance potential divider to line probe. Accuracy is plus or minus 5 percent. First model is for systems up to 11 kv. and second for systems up to 33 kv.—*Ferranti Electric, Inc., 30 Rockefeller Plaza, New York, N. Y.*

Mention No. 547 when filling out card.

Electron Tube Testers

Two new testers for testing radio, television, mobile transmitting and industrial electron tubes, feature an exclusive ohmmeter-type shorts and leakage test which indicates "Replace" or "Good" directly on tester's illuminated

975

instrument; direct indication for all other tests; an easy-to-operate gas test; and a combined emission and transconductance test under dynamic operating conditions which takes relative tube life into account. In addition to twelve sockets, facilities for unannounced types are included. Portable "Type 220" is housed in steel case with a heavy-duty metal handle and removeable cover; Counter "Type 219"

ULTRA-SENSITIVE
ELECTRONIC
RELAY

FEATURES

SENSITIVE — Relay action initiated by external contact as high as ONE HALF MEGOHM with current as low as 1/10000 ampere.

LOW COST — Electronic sensitivity and features at a cost comparable to ordinary relays.

SMALL SIZE — Mounts on a standard 4 inch electrical connector box.

DEPENDABLE — Simplified circuit plus silver relay contacts assures long service life.

ECONOMICAL — No tube filaments to consume power during "OFF" cycle.

VERSATILE — High contact pressure on silver contacts allows conservative rating of four (4) amperes, with a choice of either opening or closing a circuit, or to simultaneously open one and close another.

AUTOMATIC HOLD CIRCUIT — Connecting terminals provide a choice of conventional relay action, or allow a momentary contact to energize relay and cause it to automatically remain energized until manually reset by "Reset" switch.

APPLICATIONS

LIQUID LEVEL CONTROLS
SAFETY ALARMS
STOP MOTIONS
DROP WIRE DETECTION

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products co
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RELAYS *and* **TIME SWITCHES**

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of Diamond Quality

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With Plug-in
Tube Base
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Delayed
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Automatic
Circuit Control
"Current" and
"Potential" Relays

Ruggedly constructed to exacting specifications that are carefully engineered to provide ample safety factor . . . quality all the way through!

Automatic's relays are not built to a price but to an unexcelled standard of performance. That's why they are the choice of so many "big name" manufacturers.

We engineer and build a wide variety of stock model relays for practically all applications. A staff of competent engineers will design and build relays to fit *your* requirements.

Stock models or custom built, every relay we manufacture will deliver the same dependable performance that has made the "Diamond Seal" line the choice of those who measure *quality* by *performance*.

- **TIME SWITCHES — Equipped with Synchronous Self-Starting Motors and Silver Contacts.**

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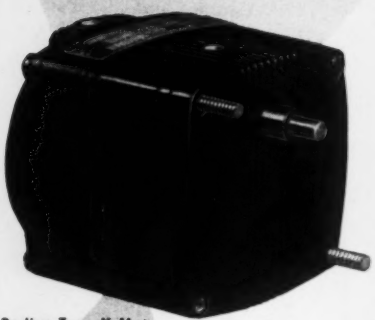


Bodine Type K Motor with Speed Reducer

Quality instruments require precision-built electric motors. That is why many leading manufacturers of instruments specify Bodine fractional horsepower motors.

The Bodine Type K motor, available with or without speed reducer, is a highly dependable source of compact power. Normal 60-cycle output ranges from 1/2000 hp to 1/500 hp on continuous duty.

Call upon Bodine engineers to help you select the proper motor to meet your instrument needs. Bodine Electric Co., 2244 W. Ohio Street, Chicago 12, Illinois.

BODINE

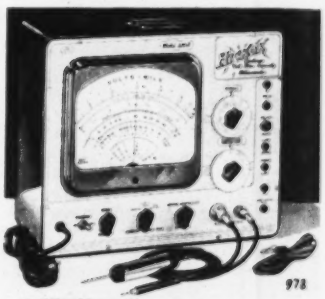
FRACTIONAL HORSEPOWER MOTORS

has identical electrical characteristics and is housed in a wood and metal cabinet. A special baked-on clear lacquer protects the panel lettering of both models. Portable and counter types measure 6" x 11¼" x 17" and 5¾" x 13" x 18¾" respectively. Both types weigh 19 pounds and are rated at 20 watts; 105/125 volts; 50/60 cycles.—*Radio Tube Div., Sylvania Electric Products Inc., 500 Fifth Ave., New York 18, N. Y.*

Mention No. 548 when filling out card.

Multi-purpose Electrical Tester

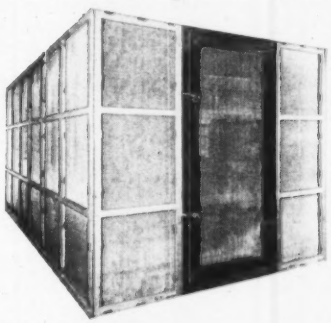
New "Model 209-A" tester measures resistance as low as 0.1 ohm, capacitance down to 1 micromicrofarad, and conventional ranges of currents and voltages. Peak to peak voltage measurements are made, and a zero-center d-c. scale is provided for improved accuracy. Instrument is complete with low-capacity high-frequency probes and test leads. Dimensions are 13.25 by 16.25 by 7 in., and weight is 18.5 lb. Operation is from 115 v. 60 cps.—*Hickok Electrical Instrument Co., 10519 Dupont Ave., Cleveland 8, Ohio.*



Mention No. 549 when filling out card.

Pre-built Screen Rooms

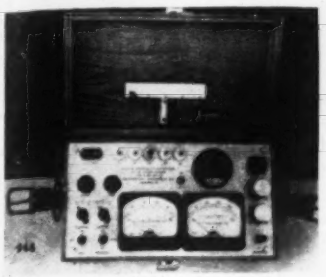
New pre-built screen rooms for laboratory and production-line use offer maximum radio interference screening efficiency at no greater cost than "home built" jobs. They are available in "cell units" which permit easy construction to almost any desired size. They provide a minimum of 100 db. attenuation from 0.15 to 1,000 Mc.—*Acc Engineering and Machine Co., Inc., 3644 N. Lawrence St., Philadelphia 40, Penna.*



Mention No. 550 when filling out card.

Gish-Rooney-type Resistivity Apparatus

New "Model LLR" earth resistivity apparatus, using the Wenner four-electrode method, measures currents on a 0-5-50-500 milliammeter, and potentials on a null-type instrument in-



dicating ranges of 0-10-100-1000 mv. No current is drawn from the potential electrodes during this measurement. An external galvanometer may be connected if extra sensitivity is needed. Apparatus is mounted in a hardwood case with waterproof finish. It is intended for measurements on conditions at 300 ft. depth or less.—*Geophysical Instruments Co., Arlington, Va.*

Mention No. 551 when filling out card.

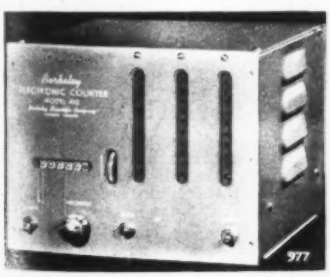
Thermostat-controlled Logarithmic Attenuator

New "Model 511 Logaten" logarithmic attenuator has a thermostat drawing 1.5 amp. at 6.3 v. which maintains an internal temperature of 100 F. Attenuator is a network of nonlinear circuit elements adjusted to give an output voltage which is proportional to logarithm of input voltage. Units are available for both d-c. and a-c. applications. Suggested uses are: to convert an ordinary VTVM or oscilloscope to a wide-range decibel meter; for compression of signals with an excessive dynamic range; for computing, where addition or substraction of voltages is equivalent to multiplication, expressed in decibel form; and to give linear-decay curves in reverberation studies.—*Kalbfell Laboratories Inc., 1076 Morena Blvd., San Diego 10, Calif.*

Mention No. 552 when filling out card.

Electronic Counter

New "Model 410" high-speed electronic counting instrument operates at speeds greatly in excess of those possible with mechanical counters. Unit will operate over a range of 0 to



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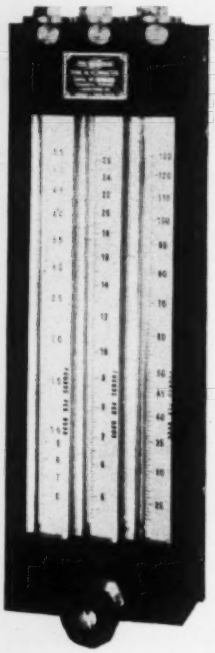


Three-Stage Model Flowmeter, Type 10

Direct Reading Saves Time

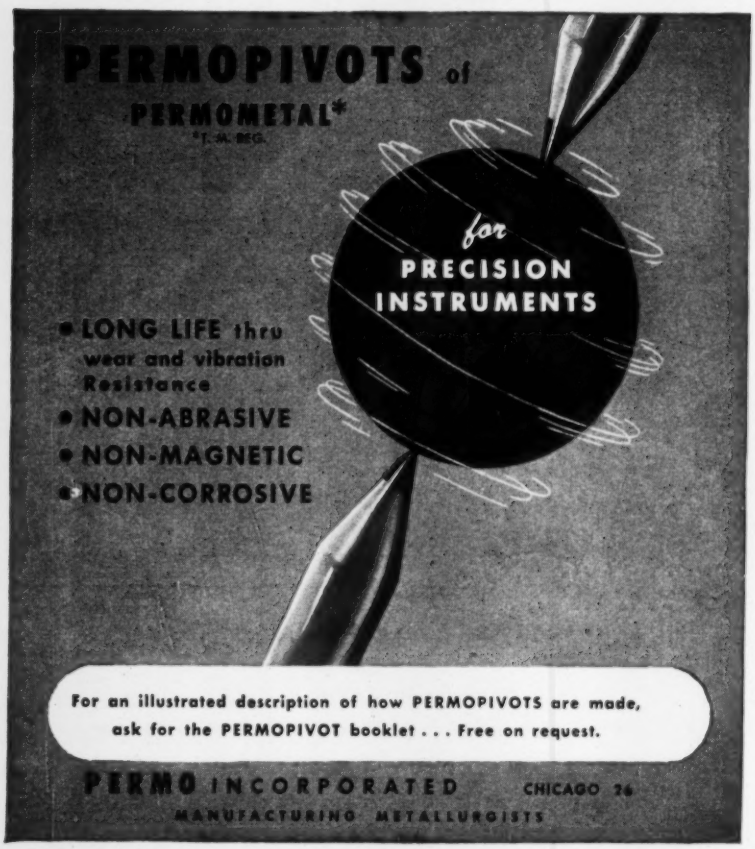
The DIRECT READING TYPE 10 FLOWMETER saves time by indicating liquid flow rate precisely and directly in the most convenient units.

50 to 90% reduction of inspection time is an accomplished fact in the testing of pumps, engines, carburetors, carburetor jets, fuel nozzles, flow control orifices, and other devices.

Write for Bulletin IM-6

COMMERCIAL RESEARCH LABORATORIES
DETROIT 3, MICHIGAN

Makers of COX INSTRUMENTS *Since 1912*

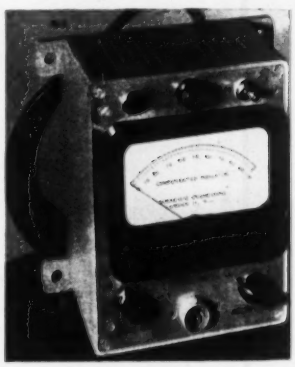


10,000 counts per second. It will count random or regularly occurring events with equal facility (provided that minimum time between any two counts is 20 microseconds). First 999 events are read directly on illuminated panel. A 6-digit mechanical register extends range to 1,000,000,000 counts. Counting may be started and stopped manually or electrically. Outputs may be obtained after 10, 100, or 1000 counts to actuate a signal.—*Berkeley Scientific Co., Sixth and Nevin Ave., Richmond, Calif.*

Mention No. 553 when filling out card.

Self-powered Indicator for LVDT Pickups

New "Type 160AD-1" indicator for use with maker's "Series S, SP, and C" linear variable-differential transformers, (LVDT), is self-contained, line-powered, and supplies a source of 60 cps. current for an LVDT which is

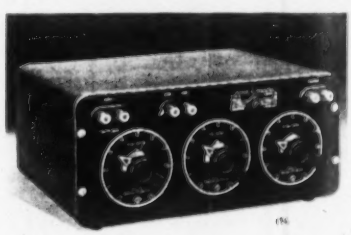


compensated for a 15-percent deviation in line voltage. Indicator scale is 3.9 in. long, calibrated 0-100 in 50 divisions. Range-multiplier switch gives 2, 4, 10, and 20 times sensitivity, to cover 0.033 to 1.0 in. when using LVDT pickups.—*Schaevitz Engineering, Cresent Blvd. at Drexel Ave., Camden 11, N. J.*

Mention No. 554 when filling out card.

Precision Attenuators

New precision decade attenuators for laboratory use and for building into other equipment are designed to operate at audio and low-radio frequencies.



Compartmented metal casting which affords such excellent shielding between pads that some units can be operated at frequencies as high as 1 Mc. with errors of less than 2 percent.—*General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass.*

Mention No. 555 when filling out card.

Cable-fault Locator

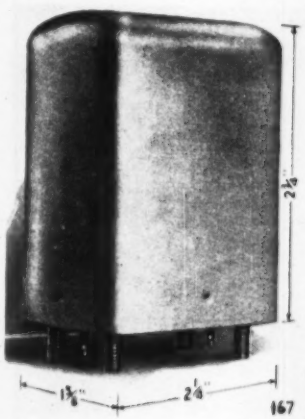
New "Model 2-2" cable-fault locator is rated up to 20 kv. with a discharge capacitance of 2.5 microfarads, for use with all cable up to 15 kv. or higher. Power requirement is about 500 watts

at 115 v., 60 cps. Unit is a high-voltage d-c. impulse generator equipped with a pickup coil and indicator. It will work with nearly all types of cable including lead-sheathed. Operation depends only on impulse voltage needed to break down fault.—*James G. Biddle Co.*, 1316 *Arch St., Philadelphia 7, Pa.*

Mention No. 556 when filling out card.

Miniature High-voltage Power Supply

New "Model 103D-6" miniature vibrator-type power supply operates from 3-v. battery and delivers 900-v. d.c., regulated to within one percent for a battery voltage from 2.2 to 3.5 v. Power



from a few milliwatts to about 3 watts can be furnished at voltages up to 2500. Unit is available for fixed or plug-in mounting, and has a life of over 1000 hours. Dimensions 1.625 by 2.312 by 2.75 in.; weight 12 oz.—*Eltron Inc., Jackson, Mich.*

Mention No. 557 when filling out card.

Adjustable Power Supplies

New series of power supplies are stabilized with a direct-coupled amplifier controlling a pair of thyratrons. "Standard" series of 250-watts output holds within 0.5 percent for line-voltage

Speedy • Accurate

RESISTANCE MEASUREMENTS

... with the Rubicon
PORTABLE WHEATSTONE BRIDGE

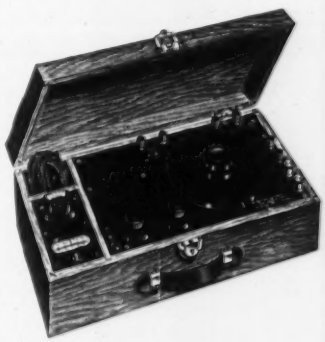
This convenient instrument combines instant portability with high accuracy and is widely used in laboratory, plant and field. Built for dependable service under hard usage.

- Wide range: 1 ohm to 10 megohms
- Limit of error: 0.1%
- Built-in battery and galvanometer
- Provision for external battery and galvanometer when required
- Available with Murray and Varley loop circuits
- Compact and rugged

... with the Rubicon
PORTABLE KELVIN BRIDGE

For work at very low resistance levels this instrument is the counterpart of the Wheatstone bridge shown above.

- Range: 0.0001 to 10.1 ohms
- Limit of error: 0.25%
- Built-in battery and high sensitivity "Pointerlite" galvanometer
- Provision for external battery and galvanometer when required
- Sturdy and convenient in operation



Wheatstone and Kelvin bridges in a variety of models, together with other resistance measuring instruments, are fully described in Bulletin 100 available on request.

SPOTLIGHT GALVANOMETER
- Sturdy, short period
- Sensitive (up to 0.0006 μA per mm.)
- Multiple-reflection optical system
- For null or deflection measurements

Described in Bulletin 320

OTHER RUBICON INSTRUMENTS

Resistance Standards • Mueller Bridges • Precision Potentiometers • Evelyn Photoelectric Colorimeter for chemical analysis • Automatic Recording Photometric Analyzers for NO and H₂S • Magnetic Permeameters • Magnetic Hardness Testers • Shorted-Turn Coil Testers • Other equipment involving precise measurement of electrical quantities.

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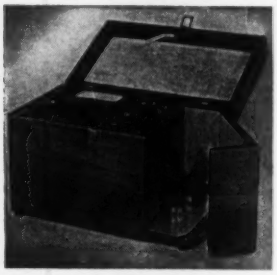
S·S·White MOLDED RESISTORS

The All-Weather Resistors

ARE USED IN THIS SUPER-SENSITIVE ULTROHMETER

An S.S.White 100 Megohm Resistor is used as the plate load resistor for the first tube in the D.C. amplifier in this instrument which measures very small D.C. currents and voltages over an extreme range of values. The manufacturer, Beckman Instruments Division of National Technical Laboratories, says of the S.S.White Resistor "it has been very satisfactory"—which checks with the experience of many other electronic equipment manufacturers who use S.S.White Resistors.

Photo courtesy of National Technical Laboratories, So. Pasadena, Calif.



WRITE FOR BULLETIN 4906

It gives essential data about S.S.White Resistors including construction, characteristics, dimensions, etc. Copy with price list on request.

S.S.WHITE RESISTORS

are of particular interest to all who need resistors that have inherent **low noise level** and **good stability** in all climates.

HIGH VALUE RANGE
10 to 10,000,000 MEGOHMS

STANDARD RANGE
1000 OHMS to 9 MEGOHMS

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MOLDED PLASTICS PRODUCTS—MOLDED RESISTORS

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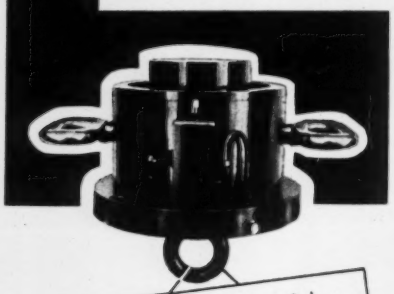


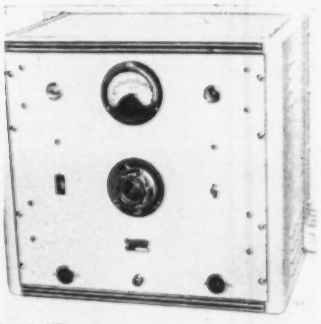
a complete line of hydraulic components: load cells for compression and tension; load indicators; strip and circular chart recorders; hydraulic jacks, valves, tools, and other special devices.

for use in applications such as dynamometers, industrial weighing, strength of structures, jet engine thrust, and countless other force-measuring problems. Illustrated is the famous Emery Hydraulic Cell, basic unit of Emery hydraulic testing and force-measuring systems.

All components are simply constructed, but rugged; they are compact in size, extremely sensitive and accurate. Easy to mount and use. Send for complete literature and prices; also our engineers will be pleased to discuss your force-measurement problems and make recommendations.

THE A.H.EMERY CO. · 75 YEARS · HYDRAULIC WEIGHING

THE A. H. EMERY CO. STAMFORD, CONN.

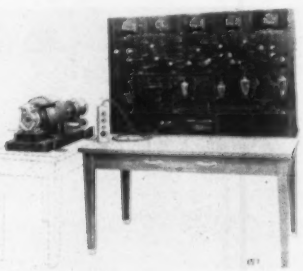


variation of 90 to 130 v. "Super" series is regulated to within 0.1 percent. Each of series has a continuously-variable output up to full rating.—*Industrial Div., Amplifier Corp. of America, 398-17 Broadway, New York 13, N. Y.*

Mention No. 558 when filling out card.

Educational Motor-control System

New "Thy-mo-trol" demonstration equipment consists of circuit and instrument panels assembled on a steel frame mounted on a composition-top steel table with complete component



complement and motor with tachometer needed to demonstrate Thyratron control of a reversing motor.—*Educational Section, Apparatus Dep't, General Electric Co., Schenectady 5, N. Y.*

Mention No. 559 when filling out card.

VTVM-ohmmeter Kit

New "Model HV345K" VTVM-ohmmeter kit is first of a line to be merchandised by Merit Electronic Instrument Co. (maker's Kit Div.). Ranges

ar- for d.c., 0-5-25-100-250-500-1000-250-10000-25000 v.; for a.c. the conventional ranges; for resistance, 5 ranges up to one billion ohms; db ranges from minus 20 to plus 62; and a zero-center discriminator alignment scale.—*Radio City Products Co., 152 W. 25th St., New York 1, N. Y.*

Mention No. 560 when filling out card.

Wide-range D-c. A-c. Chopper

New "Type 268" chopper is rated for 10-500 cps. operation, but may be used up to 800 cps. Contacts are s-p.d-t. with nominal ratings of 10-v.

0.001-amp. d.c. which may be exceeded for intermittent duty. Coils are for 6, 12, 18, and 26 v. with respective d-c. ratings of 42, 160, 390, and 800 ohms. Mounting is hermetically sealed, with 8-pin octal base.—*Stevens-Arnold Inc., 22 Elkins St., S. Boston 27, Mass.*

Mention No. 561 when filling out card.

Multi-purpose Electrical Tester

New "Series EV-20" portable VTVM and multi-range test set offers 48 ranges to 1200 v., 2000 megohms, 12 amps, plus 63 db. and d-c. VTVM ranges

to 12,000 and 30,000 v. with test probe. Two 1.5 v. flashlight cells are used. Instrument uses 200 microamp. indicator, and is housed in heavy-gage steel case with plastic handle and aluminum panel.—*Precision Apparatus Co., Inc., 92-27 Horace Harding Blvd., Elmhurst, L. I., N. Y.*

Mention No. 562 when filling out card.

Sweep-signal Generator

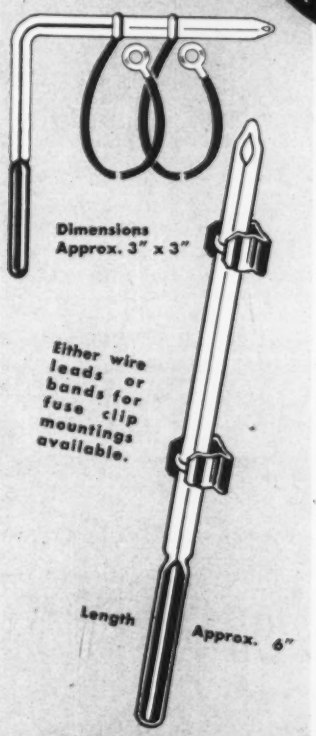
New sweep-signal generator designed for servicing FM and TV receivers has FM-sweep range from 0 to 600 kc., and TV-sweep 0 to 15 Mc. Fundamental output frequencies range from

ASICO

THERMOSTATIC TEMPERATURE CONTROLS

They Act with Accuracy

(WITHIN A FRACTION OF A DEGREE)



ASICO thermostats are manufactured to customers' specifications within the normal range of mercury thermometers.

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Write for Bulletin 52

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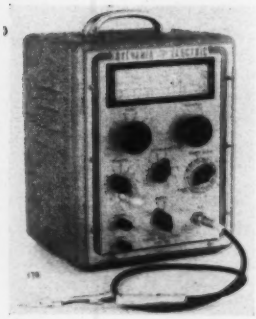
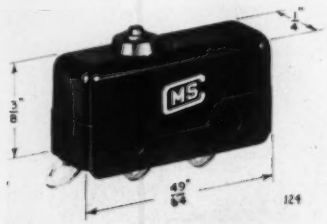


2 to 230 Mc. in four bands. Output is at least 100 mv. on all bands. Double shielding prevents signal leakage and frequency stability is assured by voltage-regulated power supply. Voltage for driving or synchronizing horizontal oscilloscope deflection is provided.—*Radio Tube Div., Sylvania Electric Products, Inc.*, 500 *Fifth Ave., New York* 18, *N. Y.*

Mention No. 563 when filling out card.

Micro Switch

New "No. 1SM1" micro switch measuring 0.765 by 0.375 by 0.25 in.; operates with a force of 27 oz., releases at 1 oz., has a movement differential of

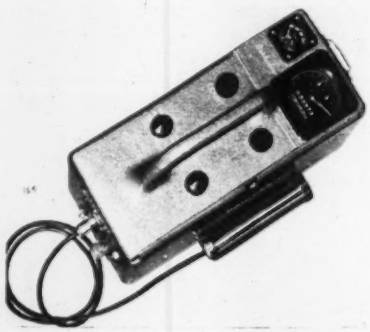


0.03 in., a pretravel of 0.008 in., and an overtravel of 0.005 in. Contact ratings are 5 amp. at 115 to 230 v., a.c., and 2 amps. at 28 v., d.c.—*Micro Switch, Freeport, Ill.*

Mention No. 564 when filling out card.

Portable Battery-operated Scaler

New "Model 80" scaler is designed for accurate determinations of radioactive levels where power supplies are not available or where line transients

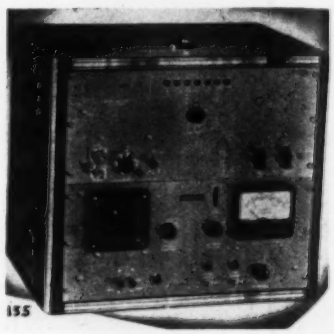


make conventional scalers unreliable. Instrument consists of a G-M tube and probe, a scale-of-eight electronic counter, a mechanical register, and an adjustable high-voltage battery supply. It has a max. continuous-counting rate of 14,400 per minute and will resolve individual pulses at 90 microseconds.—*Berkeley Scientific Co., Richmond, Calif.*

Mention No. 565 when filling out card.

All-purpose Scaler

New "Ultra-Scaler" works with Geiger, proportional, or scintillation counters. A built-in timer permits counting up to a pre-set time or a total number of counts. Resolution-time of



scaler is 2 microseconds. Stabilized voltage up to 2500 is available. Time-delay circuit prevents over-voltage on counter tube during start up. Instrument is designed for use as a monitor if needed.—*Nuclear Instrument and Chemical Corp.*, 229 *W. Erie St., Chicago, Ill.*

Mention No. 566 when filling out card.

Pulse Rise-time Indicator

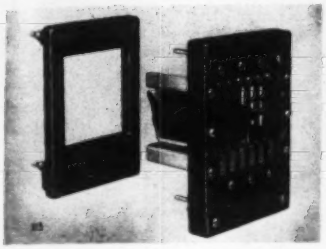
New "Model 632-B" pulse rise-time indicator has voltage sensitivity for positive-peak pulses from 1 to 200 volts. Rise-time range is 0.005 to 0.1 microseconds in 20 steps, with a max. error

of plus or minus 0.005. Pulse-repetition rate at allowable source impedances is up to 1 Mc. from 30 to 100 ohms; to 0.25 Mc. from 100 to 200 ohms; and to 100 kc. from 200 to 500 ohms.—*Electronic Systems Co.*, 555 *E. Tremont Ave., New York* 57, *N. Y.*

Mention No. 567 when filling out card

High-speed Relays

New "HHA" high-speed relays are built to operate over one million times at speeds from 6 to 8 milliseconds. Six s-p.d-t. contacts arranged side-by-side provide 28 different contact combina-

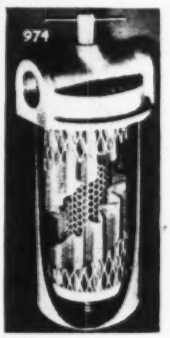


tions. Coiled beryllium spring, in face of core, pressing against armature provides pressure. Contacts and prongs are of one-piece construction. Contacts are visible through glass cover. Coils are furnished for 24 to 150 v., d.c.—*The Autocall Co., Shelby, Ohio.*

Mention No. 568 when filling out card.

Hydraulic-line Filter

New liquid-line filter is available in unit capacities of 5, 8, 10, 20, 30, and 50 GPM. Screens furnished range from a coarse 30 to a fine 200. Filter may

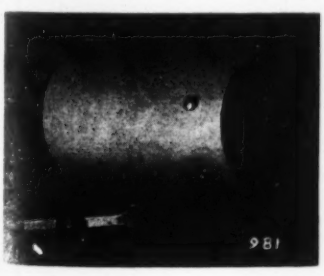


be mounted in any position, and may be disassembled for cleaning by removing one hand nut.—*Marvel Engineering Co., 625 W. Jackson Blvd., Chicago 6, Ill.*

Mention No. 569 when filling out card.

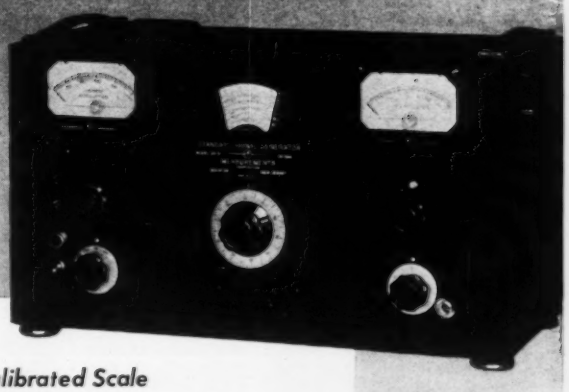
D-c. Integrator-motor

New "Integrator Motor" is for applications requiring time integral of a d-c. voltage. Its speed is proportional, within 0.5 percent, to applied voltages between minus 15 and plus 15 volts (actually proportional within 0.25 per-



STANDARD SIGNAL GENERATOR

MODEL 65-B
RANGE 75 KC to 30 MC



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OUTPUT: Continuously variable, .1 microvolt to 2.2 volts.
OUTPUT IMPEDANCE: 5 ohms to .2 volt, rising to 15 ohms at 2.2 volts.
MODODULATION: From zero to 100%. 400 cycles, 1000 cycles and provision for external modulation. Built-in, low distortion modulating amplifier.
POWER SUPPLY: 117 volts, 50-60 cycles, AC.
DIMENSIONS: 11" high, 20" long, 10¼" deep, overall.
WEIGHT: Approximately 50 lbs.

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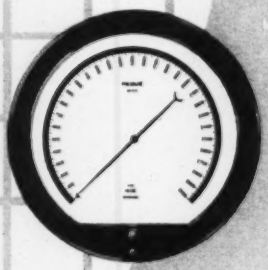

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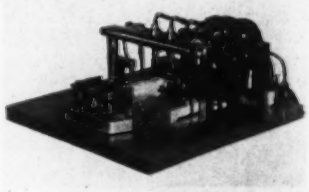
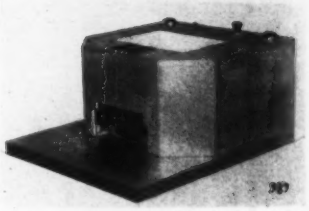
cent throughout range except near zero voltage, or reversal point). Angular shaft displacement over any given period, therefore, is proportional to integral of applied voltage during that period. Output shaft may be geared or directly coupled to an indicator or other instrument load. In model illustrated, armature is geared to a single output shaft at a ratio of 500 to 1. An alternate model can be supplied with armature geared to two output shafts, at ratios of 100 to 1 and 1,000 to 1. Extremely high torque-to-inertia ratio: 400,000 to 1 at 1 volt applied. Motor starts and runs on energy supplied by a photocell exposed to sunlight. Weight of motor 12 oz.; greatest over-all dimension 3.75 in.—*Specialties, Inc., Skunks Misery Rd., Syosset, L. I., N. Y.*

Mention No. 570 when filling out card.

Instrument Cleaner

New "Eng-Sol" method of cleaning instruments automatically sprays components with a chlorinated hydrocarbon of high specific gravity which removes all foreign matter, leaving microscopically clean surfaces. Automatic cleaning features air blow-off, cleaning of 4,500 parts with one quart of spray in 8.3 sec. per operation, and automatic unloading. Unit requires 500 watts at 115 v., 60 cps., and 6 cu. ft. per min. compressed air.—*Passaic Analytical Labs., 224 Aycrigg Ave., Passaic, N. J.*

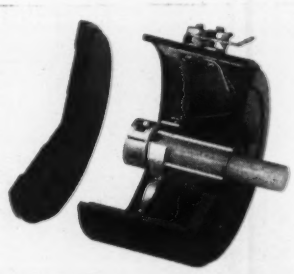




Mention No. 571 when filling out card.

Potential Divider

New improved version of "Type RV3" precision potential divider is available in two types, "RV3-8" (8

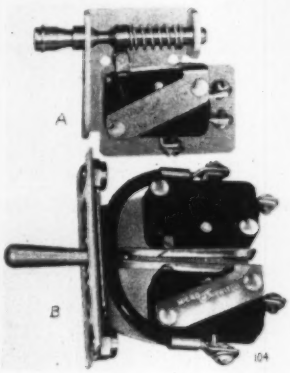


watts), and "RV3-12" (12 watts). Features include: bronze bushings for rotor shaft; tapped-mounting inserts; rotor-take-off slip ring constructed of silver-overlayed brass; dustproof construction with Bakelite cover; molded parts of low-loss mica-filled Bakelite.—*Technology Instrument Corp.*, 1058 *Main St., Waltham* 54, *Mass.*

Mention No. 572 when filling out card.

Micro Switches

New "No's. 2AC1 and 3AC1" micro switches (A) with solder and screw terminals respectively are mounted to act as door interlocks for safety circuits. Switch may be manually closed with door open for testing, but will return to safe position as soon as door is closed again. New No's. 1AT1 and

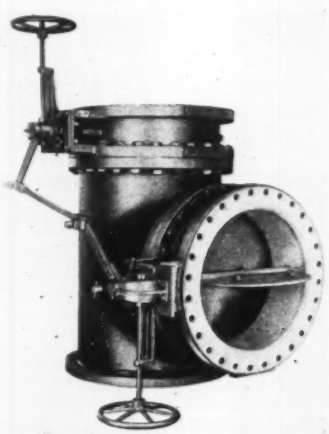


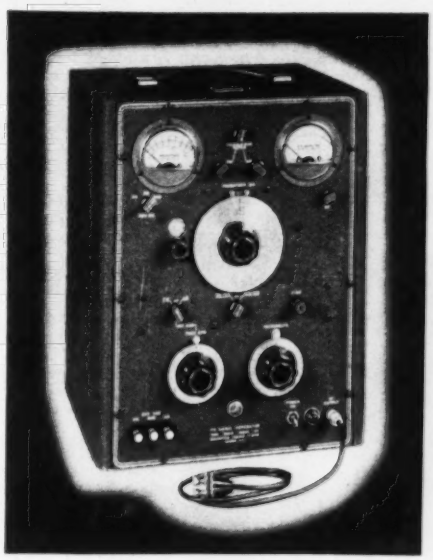
1AT2" micro switches (B) with single-throw and double-throw switches respectively are three-position momentary-contact toggle switches. Contacts on all above switches may be had in ratings of 10 amp., 115 to 250 v., 60 cps.; 10 amp., 28 v., d.c non-inductive; 6 amp., 28 v., d.c. inductive rating.—*Micro Switch, Freeport, Ill.*

Mention No. 573 when filling out card.

Rubber-seated Valves

New "No. 733" rubber-seated valves are drip-tight with water at 100 psi. and air-bubble-tight at 80 psi. under temperatures up to 275 F. and down to minus 40 F. Valves are 30 in., attached





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SIGNAL GENERATOR
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54-216 Megacycles

Specifications:

RF RANGES: 54-108, 108-216 mc. ±0.5% accuracy. Also covers 0.4 mc. to 25 mc. with accessory 203-B Univerter.

VERNIER DIAL: 24:1 gear ratio with main frequency dial.

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AMPLITUDE MODULATION: Continuously variable 0-50%, calibrated at 30% and 50% points.

MODULATING OSCILLATOR: Eight internal modulating frequencies, from 50 cycles to 15 kc., available for FM or AM.

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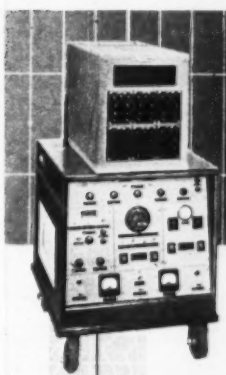

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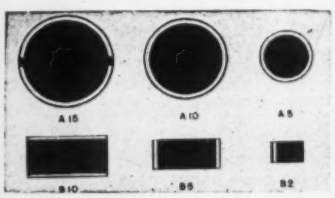

Cell	Size	Output-μa*
A15	2" diam.	800
A10	1¾" diam.	550
A5	1⅛ diam.	250
B10	1-11/16"x⅞"	340
B5	1-7/16"x41/64"	220
B2	23/32"x7/16"	75

*At 100 ft.—Candles & ext. Resistance of 100-ohms

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to a 30 in. American Standard tee, and are provided with handwheel controls with declutching mechanisms and outboard-gooseneck bearings. Valves may be operated indvidually, in unison, or may be automatically controlled.—*R-S Products Corp., Wayne Junction, Philadelphia* 44, *Pa.*

Mention No. 574 when filling out card.

Flow-operated Switch

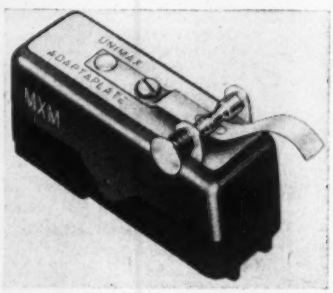
New flow interlock dimensions are approximately 2.5 by 3 by 7 in. In operation it closes a contact when a flow of water exceeds a preset amount and opens it when a flow falls below present amount. Adjustment can be

made to control circuit for any flow from one to four gpm. Flow differential between cut-in and cut-out is 0.2 gal. min. and 0.4 gal. max. Electrical rating of 10 amps. at 125 v., 5 amps. at 250 v., and 3 amps. at 460 v., all a.c. Max. line pressure is 125 psi.—*General Electric Co., Schenectady* 5, *N. Y.*

Mention No. 575 when filling out card.

Safety High-voltage Interlock

New "Model MXM" interlock automatically restores switch to safety position after manual latch-in for testing. Mechanism consists of leaf-type actuator for opening contacts when door



or panel of protected enclosure is opened as little as 0.125 in., and an automatic slide-cam which allows contacts to be closed while switch is being worked on, but restores safety feature as soon as door is closed.—*Unimax Switch Div., The W. L. Maxson Corp., 460 W. 34th St., New York* 1, *N. Y.*

Mention No. 576 when filling out card.

Screw Driver with Built-in Flashlight

New "Amberyl" flashlight screw driver comes in 0.125 by 4 in. blade,

0.3125 by 5 in. blade, and 0.1875 by 5 in. Phillips No. 1 bit.—*Vaco Products Co., 317 E. Ontario St., Chicago* 11, *Ill.*

Mention No. 577 when filling out card.

Vibration Isolators

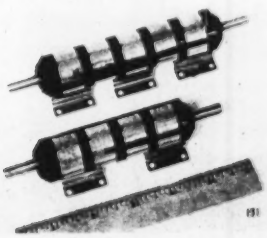
New "Type F" vibration isolators have housings of malleable castings, sealed by a cylindrical cork ring, which snubs horizontal thrust and prevents

metal-to-metal contact. Vertical thrust control and sound insulation are also provided. Unit is furnished with several standard spring capacities for loads from 10 lbs. to 500 lbs. per isolator.—*The Korfund Co.* 48-35-*J*, 32nd *Place, Long Island City* 1, *N. Y.*

Mention No. 578 when filling out card.

Miniature Speed Changers

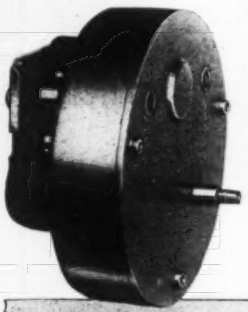
New line of miniature speed changers provides several hundred ratios between 1000:1 and 750,000:1 in addition to (500 or more) standard 1-, 2-, and 3-section units. Input speeds as



Fact-Packed Bulletin

contains valuable data on

Instrument Movements



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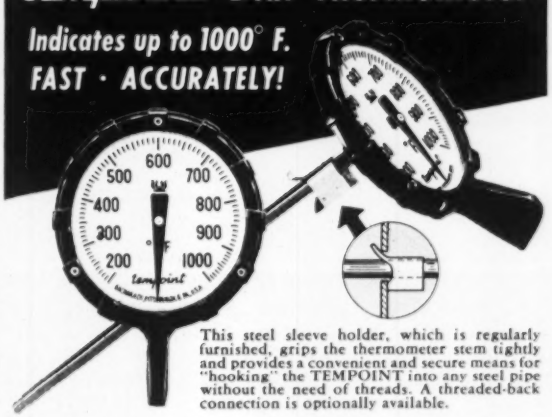

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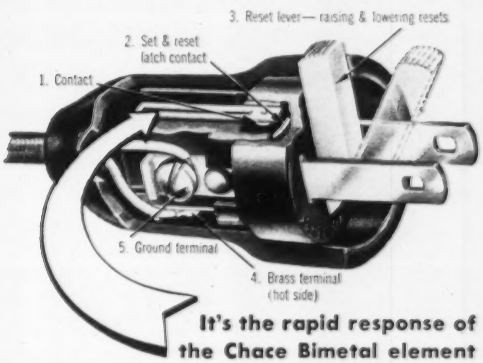

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coincidence loss, activity of sample versus half life, radiation flux after passage through absorbers, and other data. Values are obtained by simple settings of rule.—*Nuclear Instrument and Chemical Corp., 229 W. Erie St., Chicago 10, Ill.*

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Sensitive Relay

New "Model SW" relay is available in open or hermetically-sealed design. Sensitivity down to 0.003 watts s-p.d-t., or 0.012 watts d-p.d-t. is obtainable with 12,500-ohm max. coil. Contacts are silver, with rating of 1-amp. noninductive at 24 v., d.c., or 115 v., 60 cps. Mounting is single hole with locating lug, and plug-in or solder terminals.—*Allied Control Co., Inc., 2 East End Ave., New York, N. Y.*

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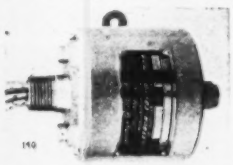
New "Model 424 Dualtrol" switch will actuate at any two predetermined pressures. Six classes of switches provide adjustable ranges from 2 in. water



to 100 psi. with proof pressures up to 120 psi. Housing dimensions are 3 in. dia. and 4.125 in. over-all. Weight 12 oz.—*Meletron Corp., 950 N. Highland Ave., Los Angeles, 38, Calif.*

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Wire-wound Resistor

New "Type 265 A" resistor is pace wound, has mica insulation, and is rated at 7.5 watts in still air and 15 watts when mounted on a metal chassis.—*Shallcross Mfg. Co., Collingdale, Pa.*

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Hydraulic Relief Valve

New cartridge-type hydraulic relief valve meets Specification AN-V-1b for Army and Navy aeronautical use; also offers new design possibilities for industry. Pressure settings range from 100 to 5,000 psi. Valve opens and closes

within a 7 per cent differential. Smaller operating differentials can be had for special applications. Valve has been tested through temperature variations from –65 F. to 160 F. with less than 5 percent change in operating characteristics. Mechanism is contained in a cartridge so designed that it may be replaced without breaking line. Pressure adjustments are made by means of an accessible screw.—*Hydraulics Div., Pantex Mfg. Corp., Pawtucket, R. I.*

Mention No. 584 when filling out card.

Thermostatic Hot Plate

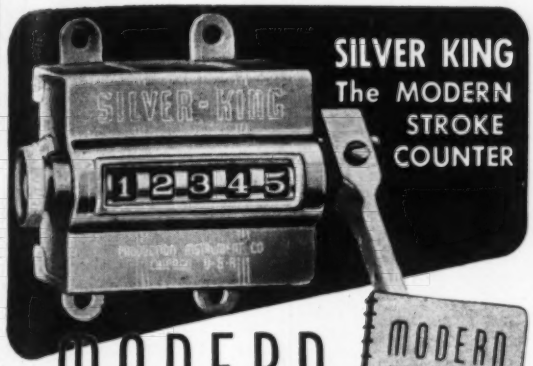
New thermostatic hot plate has built-in thermostatic heat control "No. 16633" said to make it a convenient device for maintaining liquids at approximate predetermined temperatures

from 150 to 600 F. Heating source is a Calrod unit cast into 6-inch diameter iron top. Body is stainless steel. Unit operates on 115 volts with a power demand of 500 watts, is recommended for research laboratories.—*Central Scientific Co., 1700 Irving Park Road, Chicago 13, Illinois.*

Mention No. 585 when filling out card.

MORTON—not Norton

The winner of an Honorable Mention whose entry on Fluid Proportioning was printed in our last issue (page 338) is Henry I. Morton. Sorry that we missed the first letter of his signature.



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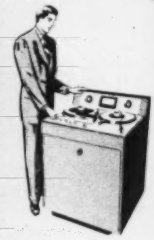

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Continued from page 444

it will aim the gun too high or low, or 'way off to the right or left, and set the time-fuze too long or too short —with errors in some cases *many times* the size of a transient error in the message. That problem stumped the experts. We've been told that their solutions using frequency-spectrum analysis and other known techniques were unsatisfactory and that Wiener's solution made the AA "brains" UNDERSTAND the noisy messages almost perfectly, PREDICT almost perfectly and COMMAND the servomotors almost perfectly. His solution was so close to a miracle that some of the best brains in the big brass said he deserved every authorized medal and a special new medal. That's what we've heard. Wiener is silent on this subject: his modesty with regard to his great specific achievement is extreme.

Is the text of Wiener's solution of the ack-ack problem the same as that of "Time Series"? Probably not. What's much more likely is that the book you can buy for four bucks contains MORE than the specific-problem secret document. To quote again from the publisher's (and Wiener's?) announcement:

"This book represents the first stage of the statistical point of view in communication engineering. It contains the specific problems of the design of linear predictors and linear wave filters."

A mathematical invention stems, as does any invention nowadays, from the giants of the past. An entire book includes the fruits of many brilliant minds. Wiener duly pays tribute to the two armies of previous workers in two great mathematical fields.

All the same, we can't understand why only linear predictors and linear wave filters are mentioned in the announcements, and automatic controllers, computing machines, etc., left out.

We began with one of the routines of a book reviewer: we criticized the title. We end with another criticism of the title: To conform with what the future control brain-box components will do, three words should be reversed, and the title should read "The Smoothing, Interpolation and Extrapolation . . ."

* * *

That we're no hero-worshipper has been made plain. That we don't consider "Time Series" a recipe for building robots that think (as some reviewers hailed "Cybernetics") has been stated and is hereby declared emphatically. The universal tool doesn't and can't exist. We cannot close this editorial without: (1) mentioning that some categories of control problems will defy solution by the "Time Series" method and by other mathematical tools not yet *invented* in flashes of genius, but will be solved by the gradual *developments* of older techniques of *applied* mathematics; and (2) mentioning that many instrumenticians are pursuing exactly this line of attack. They are the modern counterparts of the nineteenth-century giants on whose shoulders we stand. At M. I. T. and other educational centers, in the National Bureau of Standards and in industrial research laboratories, professional mathematicians are among the instrumenticians. As Kelvin gave us new and improved instruments which embodied his new applications of mathematics, so do these workers—not only by advancing the science of Automatics but more fundamentally by improving the measuring properties of measuring systems. This, too, means making our modern instrument-components more "intelligent." The totality of these efforts will undoubtedly provide a more powerful set of tools than the statistical tool of "Time Series." We may single out one example from among all these workers—the High Priest of Precision—the Director of the National Bureau of Standards:

In his *Science* article which we applauded in a brief editorial last November, Dr. Condon not only described the Instrumentation study program which the Bureau is planning but, in discussing the measuring properties of primary measuring systems, he laid stress on one particular measuring function to which he referred as "some sort of a moving time average like

$$\bar{x}(t) = k\int_{-\infty}^{0} e^{-k(t-\tau)}x(\tau)\,d\tau$$

which is based essentially on the values of x in the past for a time of the order of $1/k$." Now, dear reader, even if this equation* doesn't convey the idea, even if you have never taken elementary algebra—let alone calculus —just bear in mind these three words: *moving time average* and take a second look at our old blackboard sketch. As for the mathematical reader, we feel sure that he will smile with the joyous, eager smile of a spectator at a chess-game between masters. But there's a difference: it will be a game where everybody wins, this coming contest between those who will prefer Wiener's new tool and those who will apply the older math. AND ALL OUR READERS—THE USERS OF INSTRUMENTS—WILL RECEIVE ALL THE PRIZES WON BY ALL THE PLAYERS! —MFB

*Dr. Condon did not mean to imply, by writing the integral from minus infinity to time equal zero, that an electrical or electronic or mechanical or composite network or machine can be designed and built which will automatically take into account the complete history (since Creation) of the values of a physical magnitude (x) in a given physical system. By way of explanation—in a limited sense—of his "moving time average," we ask the reader to note Dr. Condon's use of k not only as the constant of integration but in the exponent as operating upon the expression (t minus tau) which signifies a definite, instrumentally measurable, time interval. The whole equation then apparently means (since k is inverse time) that the network or machine must be designed to take into account the succession of the values of the measured magnitude for a relatively long time interval—its "time series" as Wiener might say. Mathematically, it means that the absolute value of: (the integral from minus (one over k) to t equal zero, minus the integral from minus infinity to t equal zero) is smaller than epsilon. (Epsilon is the "arbitrarily small quantity" whose exact definition we never can remember.) Excuse this way of putting it clumsily into printed words: the way a professor would explain it to a student would have required filling half a column of this page with those long curlicues. Many of you would have turned the page and your editor would have "showed off" a mathematical case he sadly lacks.

JOURNAL of the Instrument Society of America

I.S.A. National Office, 921 Ridge Ave., Pittsburgh 12, Penna.

Vol. 6 MAY, 1950 NO. 5

Meet the Women Members of the ISA

THE ISA counts as one of its most interesting sidelights the fact that ten of its members who have, or have had, one or more of the following titles are women: Instrument maker, instrument mechanic, assistant astronomer, physicist, assistant to the president, chemist; Engineer: instrument, electrical, project, research, analytical, and petroleum. Each of the women are affiliated with one of the following ISA Sections: California, Charleston, China Lake, Cleveland, Philadelphia, Pittsburgh, Richland or Washington. Most are long term members of the Society. All have been active in Section activities. One is a Section officer.

Below are brief sketches of the educational and employment history of each. All are to be commended for their singularly impressive achievements.

Mary K. Adams—a member of the instrument division of the engineering department of the Carbide and Carbon Chemicals Division, Union Carbide and Carbon Corp., South Charleston, West Virginia. Miss Adams entered this work indirectly, having been employed by that company as a Chemist immediately upon her graduation from Denison University. She has assisted in the instrumentation of new plants of the corporation and in testing new instrument designs. Miss Adams has been a member of the Charleston Section of the ISA since 1947.

Esther Doody—received a Bachelor of Science and a graduate degree at the University of Pittsburgh, taking specialized training in spectroscopy and astrometry. She worked as a Graduate Assistant in the physics department of the University of Pittsburgh and at the Allegheny Observatory as a Computer-secretary and Assistant Astronomer. Miss Doody later worked for the Gulf Research and Development Co. in the field instruments section as a Physicist and Engineer. She is now employed as a Petroleum Engineer in the production department of the Mene Grande Oil Company in Venezuela.

Her primary interests in astronomy were double star measurements and standard wavelengths. Her work in engineering comprised development and research involving instruments used for sampling and analysis of bottom-hole (reservoir) samples of oil and gas. At present, as head of the P-V-T laboratory, she conducts tests to determine the physical properties of oil obtained from the reservoirs at bottom-hole temperature and pressure.

Miss Doody has been a member of the Pittsburgh Section ISA since 1949.

Clara Fisk—employed by the General Electric Co. in the Hanford Works at Richland, Washington, is covered by the security regulations of that plant. She has been a member of the Richland Section of the ISA since 1949.

Ruth D. Gossland—attended Cornell University and received a Bachelor of Arts degree in electrical engineering in 1942 from Stanford University. She later attended Columbia University, studying toward a Master of Science degree in industrial management.

Mrs. Gossland has worked in the electronics industry chiefly in groups concerned with telemetering instrumentation for guided-missile projects, and for manufacturers of radar equipment. Her most recent instrument employment was as Assistant Project Engineer with the G. M. Giannini Company at Pasadena, a telemetering manufacturer.

Mrs. Gossland spent 26 months in the U. S. Navy. She was the first woman officer to complete the radar engineering training course given at Harvard and at the Massachusetts Institute of Technology. She served as assistant to the Officer in charge of the electronics laboratory at the New York Navy Yard.

Mrs. Gossland is an associate member of the American Institue of Elec-

Women members of the ISA (top left to right) Mary K. Adams, Esther Doody, Clara Fisk, Ruth D. Gossland, Margaret Karns; (bottom left to right) Loren K. Lewis, Elizabeth C. Lory, Iris L. MacNabb, Dorothy D. Miller, Louise M. Suckfield

trical Engineers, a member of the Institute of Radio Engineers and has been a member of the California Section ISA since 1948. She holds a license in the state of California as a registered professional electrical engineer.

Mrs. Gossland writes: "I am chiefly interested in telemetering instrumentation and the applications to non-military use of developments resulting from this field, such as the subminiaturization of electronic circuits and their component parts. Within this branch of the instrument science, my main interest is the administrative and managerial work associated with it, rather than the purely technical development work."

Margaret Karns—attended Indiana Business College and was subsequently affiliated with Wheelco Instruments Co. She left Wheelco to join the Clarke H. Joy Co. Her special interest in the instrument field is in the design and application of thermocouples for instruments. Miss Karns has been a member of the Cleveland Section of the ISA since 1946.

Loren K. Lewis—received her Bachelor of Science degree in physics, with emphasis on engineering subjects, from the Pennsylvania State College. She later worked as research Engineer for the Kellett Aircraft Corp., Swarthmore, Pa., and worked as Analytical Engineer for the Reheem Manufacturing Co., Lester, Pa.

She is now employed by Power Generators Ltd., Trenton, New Jersey, and assumed her present position as Administrative Assistant to the President in August 1949. Her main interest in the instrument field is in hydraulic and pneumatic controllers for steam power plants boilers, feedpumps, turbines, and compressors.

Miss Lewis has been a member of the Philadelphia Section ISA since 1948.

Elizabeth C. Lory—attended Carnegie Institute of Technology, the University of Cincinnati, and graduated from Marshall College, Huntington, W. Va. with a Bachelor of Science degree, magna cum laude, in mathematics.

She has been employed in the instrument division of the Carbide & Carbon Chemicals Division, Union Carbide & Carbon Corp., South Charleston, West Virginia, since January, 1948. Her work is in making flow calculations, orifice, weir, capillary, etc., and flow charts.

Mrs. Lory has been a member of the Charleston Section ISA since 1948.

Iris L. MacNabb—received her instrument training under the sponsorship of the Army Air Force Technical Training Command, at the Chicago School of Aircraft Instruments. She also studied at the Pioneer Instrument School of the Pioneer Instrument Co. at Philadelphia, Pa., under orders from the U. S. Navy.

She worked in the experimental instrument laboratory of the Air Service Command at Wright Field, Dayton, Ohio and at the A & R Instrument Shop, Naval Air Station in Jacksonville and Miami, doing instrument overhaul work. Later she was employed in the instrument shop of the Armament Test and Flight Test Divisions at the Naval Air Test Center, Patuxent River, Maryland, as an Aircraft Instrument Maker on special instrumentation problems. Miss MacNabb's last position was in the research and development laboratory of the Science Department, at the Naval Ordnance Test Station, China Lake, California as an Instrument Maker on special types of instruments used in research and development on aircraft rockets and guided missiles.

Miss MacNabb is a member of the China Lake Section ISA.

Dorothy D. Miller—studied at Columbia and Buffalo Universities. In January of 1944 she completed a course in aircraft instruments at George Washington University, in Washington, D. C. It was from this class that the Washington Section of the Instrument Society of America was developed. Miss Miller is a charter member of that section.

Miss Miller was employed in the radio-radar section of the Procurement Division of the Naval Bureau of Aeronautics, Washington, D. C. She worked in the Office of Naval Research, and later with the Central Records Office of the Judge Advocate General, where she is now employed.

Louise M. Suckfield—received a Bachelor of Science degree in physics from the Pennsylvania State College, and took advanced courses in physics, mathematics, and instrumentation at the University of Pittsburgh. She is now employed by Gulf Research & Development Co., Pittsburgh, Pa., where she was first assigned to the seismic instrument section. She is now in the engineering instrument service section doing calibration work and instrument work on special problems.

Miss Suckfield joined the ISA in 1946. She served on the Pittsburgh Section Meetings Committee and on the Education Committee. She presented a paper on Wet Test Meters before the Pittsburgh Section in October of 1947, and a paper on Instrument Department Organization in a Process Industry Research Laboratory, at the ISA National Spring Conference in Toronto in May, 1949. Miss Suckfield is the 1949-50 season secretary of the Pittsburgh Section.

Attending ISA Meetings

An interesting article on how to attend a technical meeting entitled "Getting Your Money's Worth" by E. H. Rose, Tennessee Coal, Iron and Railroad Company, appeared in the January 1949 issue of *Mining Engineering*. While written for members of the American Institute of Mining and Metallurgical Engineers, it applies equally well to members of ISA.

The article is reprinted below with permission of Edward H. Robie, Acting Secretary of AIME.

Getting Your Money's Worth

By E. H. ROSE*

FROM the more distant members and some not so distant, the plaint is often heard that they cannot justify the expense and time required to attend the AIME Annual Meeting. Almost invariably, the reason given takes this form: "I just don't see that I would get enough out of it." Often the would-be clincher is added: "Besides, the meat of it all comes out in print anyway."

Not long ago, a group of us who have seldom missed a meeting in recent years fell to discussing this phenomenon, and found ourselves in emphatic agreement that anyone holding such a belief indicates by his first remark that he does not know how to attend a convention, and by his second, proves it. He is, by and large, the man who has never been there, and of him, there are many. Since he must often justify an expense account, these remarks are addressed to his employer as well, with the behest that prospecting for new technological knowledge or advances is like prospecting for ore or oil: the reconnaissance crews have to get out and look methodically, and in the right places, which are not necessarily the "obvious" places.

This observer does not profess to be an expert in the matter, nor even a good journeyman instructor, but some compelling points may be ticked off by anyone who has had repeated exposure to the atmosphere of mining meetings.

(1) *Information picked up in person-to-person contacts bulks for larger in take-home payoff than the official fare.* The formal presentations necessarily are contributions to knowledge in the broad sense. They deal with the contributor's experience, not the listener's. They are a one-way conversation, so to speak. The listener takes no really active part, other than discussion from the floor and that only after the speaker has had his uninterrupted say. There is no give and take concurrent with the presentation, and afterward it is too late for the knocking about of points of detail, even if time permitted, which it never does, and even if the listeners did not self-consciously "freeze" as they attempt their remarks from the floor, which many of them do.

But in the corridors, it's different. There and in the uninhibited informality of private rooms, where kindred spirits foregather, you find the source of the kind of information you came to get—the details too small or specialized to come out in the necessarily condensed formal sessions, the latest on-the-scene accounts of experiments known to be in progress but not yet advanced enough for formal reporting, the stories of experiments that failed and hence were not published to warn others away from the same blind alley, and the innumerable straws in the wind to indicate the direction of technological progress to come. There you do not take larger topics, one at a time, and exhaust them before passing on to the next. There you really get down to cases. I tell you how I am trying to do something; you come right back and tell me how you learned to do it better and you make me a sketch. You have heard that the Doakes mill has recently done itself some good by a change of flowsheet; I have recently visited that mill and tell you about it, since it is not confidential, and a Doakes man would tell you himself if he happened to be about. I have heard that the Hoozit Manufacturing Company has recently come out with a new

*Tennessee Coal, Iron, and Railroad Co.; member AIME

automatic control device; you tell me you have had one in your plant for several months and it's a honey. You have heard that my outfit is doing some work with this new method of roof pinning; that happens to be off my beat but I take you around and introduce you to a man who knows all about it, whereupon the cycle begins all over again.

Little stuff perhaps, but of good assay, and sometimes a real nugget turns up. If our friend in the first paragraph insists upon measuring dollars to the disregard of satisfactions, he might calculate that one little such item reduced to practice back home for a saving of a picayune twenty dollars a month would pay for his annual trip to the meeting, even if he came from the other side of the continent. The "regulars" know that Lloyd's would make a neat profit by writing insurance to that general effect. It is, indeed, the reason those fellows show up year after year —without insurance other than their own convictions built up out of experience.

Nor is it all little stuff. I can cite chapter and verse on two major changes of practice in large plants that came about five years sooner than they otherwise would have, as the result of just such conversations in the byways of Annual Meetings—and no confidence violated in the process. Indeed, it was discovered afterward that the basic data and interpretation pointing the way to one of them had been published as an AIME paper years before, without the potential beneficiaries reading themselves into the act.

(2) *Repeated attendance pays increasing dividends.* Implicit in the foregoing is acquaintance with those persons of the most relevant interests, and the degree of mutual benefit is measurable by the degree of mutual friendship, understanding, and respect. The standoffishness of strangers is fatal; the camaraderie of old friends, perhaps not seen since the preceding meeting, is the instantaneous catalyst that induces the real reaction of minds, and the real yield of profitable guidance on both sides. It is no accident that the mining profession is unique in being commonly referred to as the "mining fraternity" and every meeting attests the aptness of that designation. He would be a backward soul, indeed, who, after the first year or two, could come away from any Annual Meeting without at least a dozen new first-name friends, to push his circle of provincialism correspondingly outward. (It is superfluous to ask if our Doubting Thomas averages a dozen new friends a year in his field by any other means open to him, unless it be by endless travel.) Attending regularly, his contacts, instead of becoming so broad he cannot cope with them, become the more selective and fruitful. An enlightening illustration came out of the 1947 Denver Regional Meeting, when Jack Myers and I exchanged our company reports on that gathering. As Jack put it, "You wouldn't think we had been at the same meeting," for the problems and points we discussed with others were not the same problems and points, because the operations of our respective personal concern and our sources were not the same, and likewise the gleanings we deemed most worthy of reporting to our respective managements.

(3) *Reciprocity is essential.* In addition to attendance, participation in Institute activities is the key that opens the door to the benefits sought. On that point, I can speak with authority, having been an Institute member for twelve years before attending my first meeting and sixteen before serving on a committee, but thereafter diving in enthusiastically. I can correspondingly understand the mental colic of the mail-order-minded member who sends in his annual dues and expects merchandise of said value to return to him at stated intervals. The poor fellow has his frustrations coming to him, but little sympathy. He's the chap who bought a bicycle but never learned to ride it, then complains that it doesn't take him anywhere. He has never really appraised the three points made herein, or if he has appraised them, has done so under the handicap of not recognizing the Golden Rule, in professional society affairs, as not a rule at all but an automatic proportionality, truly though tritely expressed as, "You get out what you put in." The principle is that of trade; it is as simple as that.

Many inactive members sincerely believe that they are not qualified to write papers, for lack of either material or talent. Often, that may, indeed, be true, but it does not follow that they are unqualified to pursue other activities, such as serving on national or Local Section committees, all of which is as voluntary as the writing of papers and even more rewarding. Someone may say that he has never been "put" on a committee. The process is not quite so passive; one has first to open his eyes to the many ways in which he could be useful to others and thus in due process to himself and to his employer. To be selected, he must become visible. A few thoughtful letters written to the chairman of committees covering his field of work or his geographic area—making suggestions, offering criticisms, or even merely asking the questions he asks himself verbally—and he will soon find himself out on the main line moving with traffic. He can be perfectly selfish about it, not for a moment pretending that such activity on his part is out of the kindness of his heart or for love of his fellow man, but strictly on the basis that such is directly or indirectly a sound currency of trade for any of the several desirable objectives: professional recognition, technological information, a promotion, or a different job. It just happens to work that way, as many can attest. Even on a committee, there will be no one standing at his elbow telling him what to do. It is his in-time-well-rewarded job to think of something to do, just as in the conversations stressed under point (1) he must contribute information as well as seek it.

And so, the question "how to attend an AIME meeting" or even "how to be an AIME member" boils down to one simple principle: "Give and ye shall receive." The mechanics of doing so presume a smattering of originality and extraversion, but beyond that one could more simply convey the idea by defining how *not* to attend an AIME meeting: don't just sit still and wait for the manna to rain down. You will be disappointed if you do.

Buffalo Conference Instrument Maintenance Clinic

The ISA Pre-conference Instrument Maintenance Clinic, which was held for the first time last year before the St. Louis Show, will be held again on the Friday, Saturday and Sunday immediately preceding the opening of the Fifth National Instrument Conference and Exhibit on Monday, September 18, 1950 in Buffalo.

The Clinic will follow the same general plan as did the St. Louis Clinic: a series of approximately 10 sessions of 2 hours each (totaling 20 hours) will be offered on the weekend of September 15-17. Instruction will be on maintenance, repair and installation of instruments. Ten instrument companies exhibiting at the Show will provide instructor personnel and demonstration equipment. The classes will be limited to about 20 men each. Class participation will be encouraged. A social affair is to be arranged for the students on Saturday evening.

The Buffalo Clinic will be held in the rooms of the New York State Institute of Applied Arts and Sciences, Elmwood Avenue, Buffalo. Plans for the Clinic are under the direction of Mr. L. C. Laird, Chairman of the ISA Instrument Maintenance and Operations Committee, and Mr. Joseph Serpa, Chairman of the Educational Committee of the Buffalo Conference Committee.

Detailed information on times, instruments to be covered, participating companies, registration procedure, accommodations, etc., will be published in the near future.

Latest Exhibitors in Buffalo Show

In the April issue of the Journal the companies who had reserved space for the Fifth National Instrument Exhibit were listed along with their booth positions. The list covered 84 exhibiting companies who had reserved 118 booths as of March 20, 1950.

The following supplemental list covers the companies, and their booth positions, who have reserved space since March 20, 1950.

Annin Co.	219
Automatic Temperature Control Co.	333
Bacharach Industrial Instr. Co.	325
Baird Associates	225
Brabender Corp.	316
Bridgeport Thermostat Div. Robertshaw-Fulton Control Co.	228
Daven Co.	328
Eagle Signal Co.	410
Electric Autolite Co.	116
G. M. Giannini Co.	338
Gow Mac Instrument Co.	406
Imperial Brass Mfg. Co.	223
Industrial Electronics Inc.	230
Rochester Mfg. Co.	424
Rockwell Mfg. Co.	408
Servo Corp. of America	402
Streeter Amet Co.	326
Taber Instrument Corp.	326
U. S. Gauge Div. American Machine & Metal Inc.	340, 342
Vapor Recovery Systems	329
Weston Electrical Instrument Co.	227, 229

As of April 25, 1950, 139 booths have been reserved by 104 exhibiting companies. Only 26 booths remain to be sold.

Frequency Response Of Instruments*

By R. J. W. KOOPMAN†

Introduction

EVALUATION of the performance of an instrument is often made by observing its response to certain input signals, the most popular of these being the "step-function" and "steady-state" sinusoidal inputs. In electrical measuring instruments, position servomechanisms in which the position-sensing instruments are electrical, etc. the "step-function" type of input may usually be obtained by merely closing a switch. However, when testing certain other instruments which measure mechanical dynamics, such as accelerometers, it is quite difficult to produce a satisfactory "step-function" type of input.

Fourier integral analysis tells us that —theoretically at least—if we know the frequency response of a network or a system,[1] we know its transient or time response to any input expressed as a function of time. The step-function is a special, but highly popular case of the latter. The Fourier integral also establishes the reverse process.

If we find that one or the other of the standard inputs is difficult to obtain in the laboratory, we are on solid theoretical ground if we use the type of input which is obtained with facility and translate the response to this input, to the response to the desired type of input.

It was just such an experience which prompted the author to write this article. The instrument in question was an accelerometer and the customer was interested in its response to a "step-function" input. Satisfactory input of this type was very difficult to obtain in the laboratory, but a "voice-coil" type "shake table" was available so that its frequency response data were readily obtained. The method used in translating this information into the transient response is described in this article. The method is based on well known fundamentals of vibration[2,3] engineering. It is the combination and utilization of these fundamentals which the writer believes make an interesting contribution.

It will be apparent in the analysis to follow, that the method to be described must be restricted in its application to instrument damping ranges below 70.7 percent of critical. This is the price paid for simplicity. It is not necessary, however, to record the phase relationships between input and response as it would be for a complete analysis, unrestricted as to damping, by Fourier integral methods.

Description of Instrument

The instrument on which this method was used was an accelerometer having the mechanical circuit shown in Fig. 1. Acceleration was measured by the relative displacement between the mass and the case. This displacement was converted directly to a proportional electric signal. The same schematic circuit could be used for a beam-supported mass.

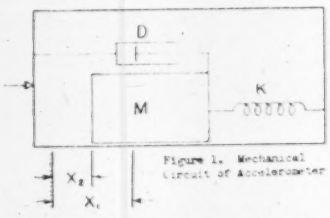


Figure 1. Mechanical circuit of Accelerometer

Analysis

It is sometimes helpful, particularly for electrical engineers, to analyse mechanical problems in terms of their electrical analogs. Fig. 2 shows the electrical analog of the mechanical circuit shown in Fig. 1. The proof of the analogy consists in writing the differential equations for each and comparing. If the equations have the same form the two are analogous.

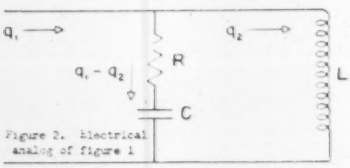


Figure 2. Electrical analog of figure 1

Consider a forced displacement x_1 to be given to the instrument case shown in Fig. 1, then

$$M\frac{d^2x_2}{dt^2} = D\frac{d}{dt}(x_1 - x_2) + K(x_1 - x_2) \qquad (1)$$

Now consider a charge q_1 as the electrical input to the circuit of Fig. 2, then, the voltages across the two parallel branches must be equal and are given by

$$L\frac{d^2q_2}{dt^2} = R\frac{d}{dt}(q_1 - q_2) + \frac{1}{C}(q_1 - q_2). \qquad (2)$$

Thus

L	is analogous to	M
R	" "	D
$\frac{1}{c}$	" "	K
q	" "	x

We may now proceed with our analysis on the electrical basis. From a-c. circuit theory we can write from inspection that

$$\frac{q_1 - q_2}{q_1} = \frac{\dfrac{1}{R + \frac{1}{jC\omega}}}{\dfrac{1}{jL\omega + \frac{1}{R + \frac{1}{jC\omega}}}}. \qquad (3)$$

If we let

$$a = \frac{\text{actual radian frequency}}{\text{undamped resonant radian frequency}} = \frac{\omega}{\omega_o},$$

$$b = \frac{\text{actual resistance}}{\text{Resistance of Critical damping}} = \frac{R}{R_c},$$

$$\omega_o = \frac{1}{\sqrt{LC}},$$

$$R_c = 2\sqrt{\frac{L}{C}},$$

$$R = b\,2\sqrt{\frac{L}{C}}, \text{ and}$$

$$\omega = \frac{a}{\sqrt{LC}},$$

equation (3) simplifies to the following

$$\frac{q_1 - q_2}{q_1} = \frac{a^2}{a^2 - 1 - 2jab}. \qquad (4)$$

In magnitude-angle form

$$\frac{q_1 - q_2}{q_1} = \frac{a^2 \angle \theta}{\sqrt{(a^2-1)^2 + 4a^2b^2}} \qquad (5)$$

where

$$\theta = \tan^{-1}\frac{2ab}{a^2 - 1}. \qquad (6)$$

For the instrument, equation (5) gives the ratio of relative displacement to case displacement. Since for sinusoidal displacements the acceleration is ω^2 times the displacement,

$$\frac{\text{relative displacement}}{\text{acceleration}} = \frac{1\angle\theta - \pi}{\omega_o^2\sqrt{(a^2-1)^2 + 4a^2b^2}} \qquad (7)$$

This is really the equation for the response of the instrument.

If the value of equation (7) were plotted against frequency ratio, "a" $= \omega/\omega_o$ for various values of "b", curves similar to those shown in Fig. 3 would be obtained. The curves in Fig. 3 are universal in that they represent the value of equation (7) for the various conditions divided by the static amplitude.

The magnitudes and the positions of the peaks on the curves of Fig. 3 can be utilized to find the response to the "step" input which is the principal objective of this article.

The maximum response of the instrument occurs when the derivative of equation (7) with respect to "a" becomes zero. On performing this operation we find

$$a^2 - 1 + 2b^2 = 0. \qquad (8)$$

For a given value of damping ratio, "b", the peak on the curve occurs at a frequency ratio

$$a = \sqrt{1 - 2b^2} \qquad (9)$$

Substituting (9) into (7) response

$$= \frac{1}{\omega_o^2} \cdot \frac{1}{2b\sqrt{(1 - b^2)}} \qquad (10)$$

The zero frequency response is $1 \angle 2$.

Note:—Statements and opinions advanced in papers are to be understood as individual expressions of the authors and not those of the Society.

*Presented at the Fourth Annual Conference of the Instrument Society of America, Sept. 12-16, 1949, St. Louis, Mo.

†Professor Electrical Engineering, Washington University, St. Louis 5, Mo.

[1]Operational Circuit Analysis, Vannevar Bush, John Wiley & Sons, Inc., New York, 1929, pages 180-181.

[2]Mechanical Vibrations, J. P. DenHartog, McGraw-Hill Book Company, New York, 1934

[3]Vibration Analysis, N. O. Myklestad, McGraw-Hill Book Company, New York, 1944

[4]Bush, op. cit. pages 56-75.

[5]Heavisides Operational Calculus, E. J. Berg, McGraw-Hill Book Company, Inc., New York, First Edition, 1929, pages 67-72

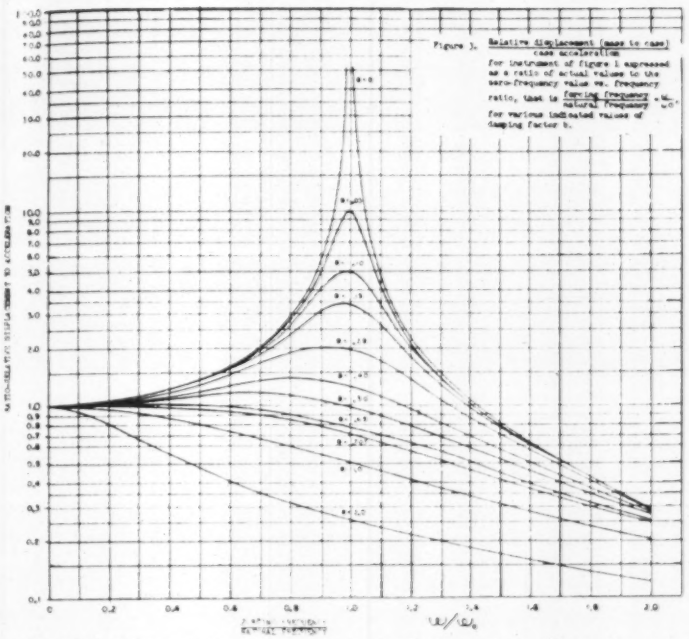


Figure 3. Relative displacement (case to case) case acceleration

For instrument of figure 1 expressed as a ratio of actual values to the zero-frequency value vs. frequency ratio, that is forcing frequency / natural frequency, for various indicated values of damping factor b.

hence the peak values of the curves of Fig. 3 for the various damping factors are given by the expression

$$\frac{1}{2b\sqrt{1-b^2}} \qquad (11)$$

A plot of the above expression against damping factor "b" is shown in Fig. 4.

Thus if the test data are presented in the form used in Fig. 3, the heights

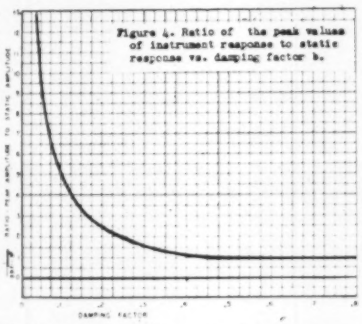


Figure 4. Ratio of the peak values of instrument response to static response vs. damping factor b.

of the peaks may be used to determine the damping factors by direct readings from Fig. 4.

Equation (9) is plotted in Fig. 5. After having determined "b" from Fig. 4, Fig. 5 can be used to determine the ratio between the frequency at which the peak response occurs and the

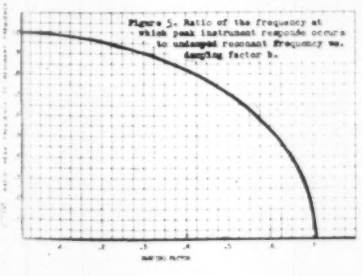


Figure 5. Ratio of the frequency at which peak instrument response occurs to undamped resonant frequency vs. damping factor b.

natural frequency. Thus the natural frequency ω_o, is determined.

The response to a step acceleration input is then given by

$$A\left[1-\frac{\varepsilon^{-b\omega_o t}}{\sqrt{1-b^2}}\sin\left(\omega_o\sqrt{1-b^2}\,t+\tan^{-1}\frac{\sqrt{1-b^2}}{b}\right)\right] \qquad (12)$$

Performance of Underdamped Instruments

It can be seen readily from both the curves and equations given that the method described breaks down for damping near 70 percent critical and above. However, there are some advantages to underdamping and not all instruments need be critically damped.

For instance, Fig. 6 is a universal curve for an instrument, such as that of Fig. 1, showing the ratio of relative

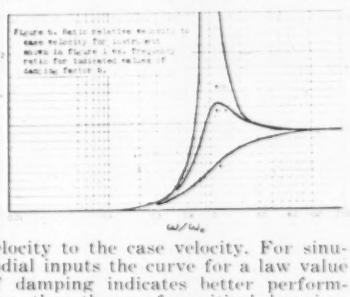
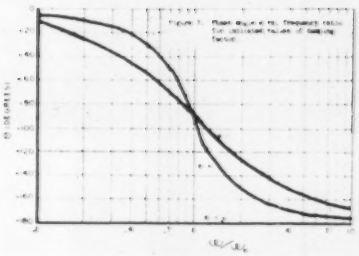


Figure 6. Ratio relative velocity to case velocity for instrument shown in figure 1 vs. frequency ratio for indicated values of damping factor b.

velocity to the case velocity. For sinusodial inputs the curve for a law value of damping indicates better performance than the one for critical damping. Again for sinusoidal inputs, Fig. 7 shows greater phase difference between input and output for high damping.

Fig. 8 shows typical transient responses to step inputs of an instrument with different amounts of damping. It is readily seen that if some error due to "over-shoot" is tolerable the time required to reach the maximum response or the time required to reach a value equal to the "steady state" value may be decreased by reducing damping.



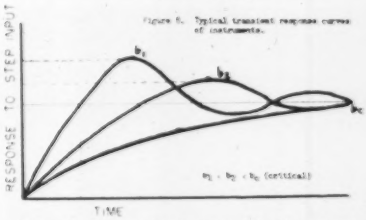


Figure 8. Typical transient response curves of instruments.

The time required to reach the maxima of these curves may be found by differentiating equation (12) with respect to time and setting the result equal to zero.

Performing this operation it is found that

$$\frac{d}{dt}(\text{Equation 12}) =$$

$$\sin\left(\omega_o\sqrt{1-b^2}\,t+\tan^{-1}\frac{\sqrt{1-b^2}}{b}\right)\frac{b\omega_o}{\sqrt{1-b^2}}\,\varepsilon^{-b\omega_o t}$$

$$-\varepsilon^{-b\omega_o t}\cdot\cos\left(\omega_o\sqrt{1-b^2}\,t+\tan^{-1}\frac{\sqrt{1-b^2}}{b}\right)=0. \qquad (13)$$

Transposing and dividing by the exponential and cosine terms, and taking into account that the tangent repeats for intervals in argument of $\pm n\pi$, equation (13) becomes

$$\tan\left(\omega_o\sqrt{1-b^2}\,t+\tan^{-1}\frac{\sqrt{1-b^2}}{b}\mp n\pi\right)=\frac{\sqrt{1-b^2}}{b}. \qquad (14)$$

from which

$$t=\frac{\pm n\pi}{\omega_o\sqrt{1-b^2}} \qquad (15)$$

This is the time required to reach the various points of zero slope on the curves shown in Fig. 9.

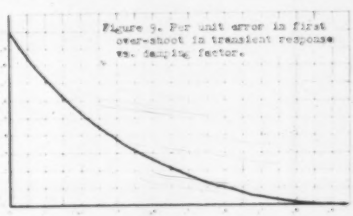


Figure 9. For unit error in first over-shoot in transient response vs. damping factor.

Taking n = 1 for the first "over-shoot" and substituting into (12), the magnitude of the first over-shoot for different amounts of damping is found to be

$$\varepsilon^{\frac{-b\pi}{\sqrt{1-b^2}}} \qquad (16)$$

The graph of this expression is shown in Fig. 9.

The time to reach the first peak can be obtained from (15), taking n = 1.

The time to reach a value equal to steady state may be found by setting

the sin term in equation (12) equal to zero.

Then

$$\sin\left(\omega_0\sqrt{1-b^2}\,t + \tan^{-1}\frac{\sqrt{1-b^2}}{b}\right) = 0 \qquad (17)$$

when

$$\omega_0\sqrt{1-b^2}\,t + \tan^{-1}\frac{\sqrt{1-b^2}}{b} = \pm n\pi \qquad (18)$$

Since the first zero of (17) is of interest we find

$$\omega_0 t = \frac{\pi - \tan^{-1}\dfrac{\sqrt{1-b^2}}{b}}{\sqrt{1-b^2}} \qquad (19)$$

These values of $\omega_0 t$ for different damping ratios are plotted in Fig. 10.

Determination of Response to Other Inputs When Response to "Step" Input Is Known

For the solution to this problem the superposition theorem[4], or as it is sometimes called, Duhamel's integral[5] may be utilized. This theorem states that the response at any given time, t, is

$$\theta_0(t) = e(0)A(t) + \int_0^t A(\lambda)e'(t-\lambda)\,d\lambda \qquad (20)$$

where e (t) is the input as a function of time

A(t) is the response to a unit "step" input.

The writer has applied this integral to the test of a position servomechanism — one of the instances cited previously in which the "step" input is easily provided in the laboratory—for position error with constant velocity input.

Fig. 11a is a graph of the input, from which we readily see that $e(o) = 0$, and hence the first term in (20) is zero. Fig. 11b is a graph of the derivative of the input function and may be seen to be constant; therefore, $e'(t-\lambda)$ is a constant. The integral term in (20) then becomes a constant times the area under the A(t) curve shown in Fig. 11c between the origin and t. This area then is proportional to the total positional output of the servomechanism for time, t. The area under the horizontal line and to the same limits is the positional output for a perfect servomechanism, that is, one in which A(t)

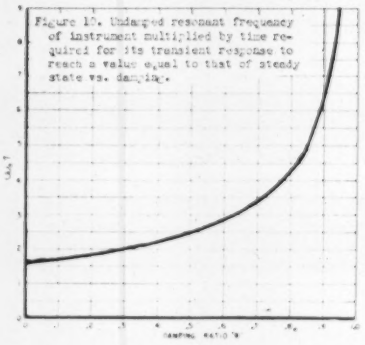


Figure 10. Undamped resonant frequency of instrument multiplied by time required for its transient response to reach a value equal to that of steady state vs. damping.

would follow exactly the "step" input. The difference between these two areas is proportional to the positional error at time, t. This fact can be used in the adjustment of a servomechanism in the laboratory, because, theoretically at least, the positional error due to velocity can be made zero if the double-hatched areas of Fig. 11c can be made equal to the single-hatched areas. The limitation on this method is that it must be restricted to the linear systems.

Conclusions

It has been shown in this article how rather simple frequency response data can be used to find the transient response of an instrument to a "step" input. While this method is limited to underdamped instruments, it is shown that in some instances the performance of underdamped instruments is preferable. It is also shown that when the

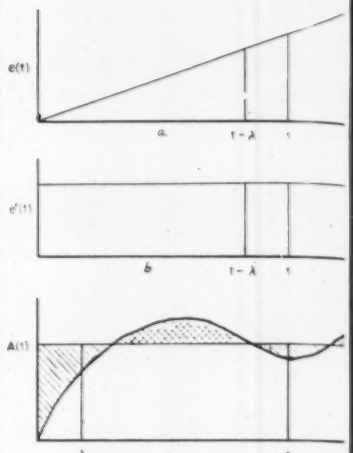


Figure 11. Graphs used in illustration of application of superposition theorem to finding time response to other input when time response to "step" input is known. a. Graph of input vs. time, t. Derivative of 'a'. c. Response to unit step input.

"step" input is obtainable in the laboratory, the response to it may be used to determine the response to other types of inputs. An illustrative example using an input increasing in time at a constant rate, often called the ramp function was given. This method could be applied to a sinusoidal input if desired, although the calculation required in that case would be tedious.

Cutting the Cost of Control*

By L. E. OBERHELMAN†

DURING the recent war and the following period of rush construction to meet consumer demand, the urgent necessity for production in the shortest possible time made the expeditious completion of design and construction of petroleum refining and chemical plants a prime consideration of engineers in these fields. Only through resourcefulness and careful planning was it possible to obtain economical construction during these times of increasing costs and limited availability of materials and labor. Shortages are no longer a serious problem, but high costs still necessitate extraordinary care in planning construction.

One factor in the economical design of a unit is the application of control equipment. It is conceivably possible to build a processing unit that is controlled and operated manually, thus entirely eliminating automatic control by instrumentation. On the other hand, it may be possible to build the same unit for control and operation almost entirely by automatic instrumentation, thus eliminating most personnel. However, neither of these extremes is practicable or economically sound. Generally 5 to 8 percent of the total cost of typical processing units is expended on instrumentation and control equipment. Although this represents a relatively modest part of the total cost, truly economical design cannot be attained without adequate consideration of every component.

Control of a process can usually be accomplished by several different methods. The selection of the particular scheme to be used should be made not only on the basis of inherent functional advantages and limitations but also on the basis of the following economic aspects: 1. Installed cost; 2. Saving through simplifications in processing equipment; 3. Operating and maintenance costs.

This article primarily concerns the reduction of installed costs of instruments and control equipment. Several examples will be cited to indicate possible economic advantages of some of the more recently available equipment. Some of the control schemes illustrated may not have been thoroughly tested in industrial practice, but all are believed worthy of consideration.

Fig. 1 shows a typical installation of a conventional indicating manometer-type pneumatic flow transmitter installed for the flow measurement of an oil having relatively low viscosity. A piping diagram for this transmitter installation is shown in Fig. 2. The complete assembly consists of orifice flanges and plate, primary block valves in the differential pressure leads, seal pots and support bracket, differential pressure lead piping (including a five valve manifold), flow transmitter, air filter and reducing valve, and the heated enclosure. If the oil is relatively non-corrosive, clean, and free from entrained water, the seal pots may be omitted. Heating of the enclosure may also be omitted if the instrument air has been adequately dehydrated to prevent formation of dew or frost within the instrument. The enclosure may be

*Presented at the Fourth Annual Conference of the Instrument Society of America, Sept. 12-16, 1949, St. Louis, Mo.

†Standard Oil Company (Indiana) Sugar Creek, Missouri.

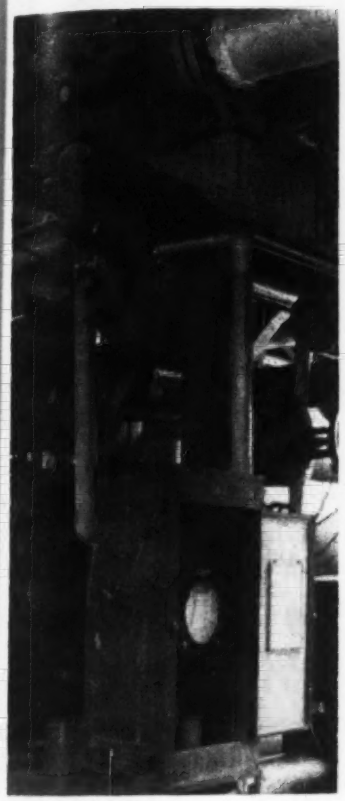


Fig. 1. Manometer-type flow transmitter for low viscosity oil.

eliminated only where weather conditions permit.

A completely different scheme of instrumentation is necessary if a substantial cost reduction is to be realized. Fig. 3 shows the piping diagram for an alternative pneumatic flow transmitter based upon using a mercury-less force-balance type of differential pressure transmitter. Where service conditions permit the use of this type of installation, the instrument selected must be made of materials to withstand the corrosive action (if any) of the process fluid. The sealing system may be eliminated if the differential taps at the orifice are located at or above the centerline of the pipe, so that appreciable quantities of entrained water (if any) in the oil cannot enter the leads. This is feasible in the case of the force-balance type of differential pressure transmitter, whereas it is not

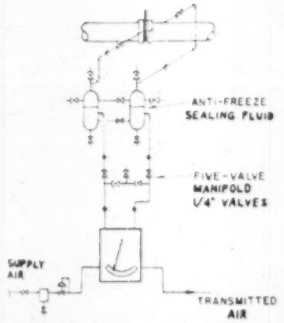


Fig. 2. Piping diagram for flow transmitter shown in Fig. 1.

feasible in the mercury-manometer type. The former involves essentially no volumetric displacement of fluid in the differential pressure leads, while the manometer type does. This displacement could result in sufficient accumulation of water to affect metering accuracy and to create a hazard in the event of freezing. The elaborate enclosure can be omitted when using the force-balance type of differential pressure transmitters because they are available in weather-resistant cases. If the process line is reasonably rigid and free from vibration, these instruments need not be separately mounted. Since they are light in weight and contain no mercury, these transmitters can generally be supported from the differential lead piping. Maintenance should be reduced because there are no meter seals to balance periodically. Piping is appreciably simplified, and the cost of fittings and labor is therefore considerable less.

In Fig. 4, the installed costs of the two alternative flow transmitter installations are represented by block diagrams. The diagram on the left represents the total cost of the manometer type of flow transmitter shown in Figs. 1 and 2. This total is made up of the cost of the instrument, the enclosure, the piping, miscellaneous items such as steam tracing and supports, and field labor. The total cost of the force-balance type of differential pressure transmitter, shown on the right, is seen to be much less than that of the manometer type.

Fig. 5 illustrates a typical installation for the flow measurement of a highly viscous oil, in which the differential pressure leads between the orifice and the manometer type of instrument must be steam traced and insulated. If the oil contains entrained water which will settle into the seal pots, the antifreeze sealing fluid will be diluted, making it susceptible to freezing in winter and affecting the accuracy of the meter. Obviously, fluid dilution must be corrected; in other words, it necessitates maintenance. From the photograph of the arrangement, it is apparent that the cost of the meter piping, seal pots, brackets and supports, enclosure, steam tracing, and insulation is relatively high compared to the purchase cost of the instrument.

The mounting and heated enclosure for the flow transmitter shown in Fig. 5 are typical of oil refinery practice in regions where cold weather is encountered. Because the instrument is heavy, a substantial steel mounting is required. The enclosure for weather protection must usually be custom-built. The pots, steam tracing, and insulation involve many labor-consuming details which make the cost of a conventional installation of this type quite high, probably higher than is commonly supposed. However, it is difficult to reduce the number of these details appreciably and have satisfactory year-around operation.

Fig. 6 shows an alternative installation for pneumatic transmission of the flow rate of a relatively viscous fluid. In applications where the transmitter is sufficiently accessible and where the process line is rigid and reasonably free from vibration and mechanical shock, a force-balance type of differential pressure transmitter may be mounted directly on the process line. The short differential pressure leads may be made of stainless steel or other corrosion-resistant tubing, with little added expense. This tubing, because of its flexibility, can readily be routed close to the main pipe so that the meter leads are kept warm, thereby keeping viscosity low enough for good metering response. The leads and the instrument can be so located and insulated as to maintain a suitable temperature, the heat being supplied from the process piping.

Fig. 7 shows a cost comparison of the manometer type of flow transmitter illustrated in Fig. 5 and the force-balance type of differential pressure transmitter illustrated in Fig. 6. The comparison does not include the cost of the instrument air supply and transmission lines which would, of course, be approximately the same in each case. A considerable difference in costs may be noted. This difference is due primarily to the elimination of the enclosure and the steam tracing, and to a reduction in the labor and piping costs.

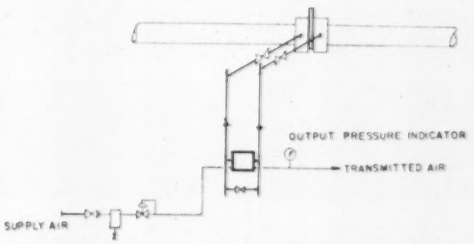


Fig. 3. Piping diagram for force-balance type differential pressure transmitters as applied in light oil service.

It should not be inferred from the preceding examples that the force-balance differential pressure transmitter can always be used, even in view of the advantage in the installed cost. A number of limitations are evident. The instrument should be located close to the orifice, particularly if it is desired to realize the cost advantage indicated in Fig. 7. This is not always practicable from the standpoint of accessibility required for maintenance and checking. Another disadvantage is that there is no direct means of ascertaining whether or not the transmitted air is at the required pressure. The air relay and pilot valves may become fouled, and therefore periodic calibration is required. On the other hand, with the manometer type of transmitter one can make a fairly close check on the accuracy of the transmitted air pressure during operation by referring to the pointer or linkage which is mechanically connected to the float on the mercury. Furthermore, the force-balance type is difficult to dampen, as is often necessary in the case of flow controllers. It is also difficult to clean without complete dissassembly. With further experience in the use of the

force-balance type of transmitter, improvements will undoubtedly be developed to overcome some of these limitations.

Fig. 8 shows diagramatically a method of heating control for a reboiler or steam heater. Such an arrangement has been used very successfully where high heat input and accurate temperature control are required. Temperature control is obtained by means of a steam flow controller that has its control point index set by a temperature controller. Fig. 9 is a photograph of a typical installation showing the steam flow controller. The control valve is relatively large to provide for maximum steam capacity at a low pressure drop. The cost of the control valve with the usual block and by-pass valves and flanges, as well as the labor for erection and insulation, is considerable. The flow-meter piping and the instrument enclosure must be kept warm with steam tracers, and the meter requires condensate pots.

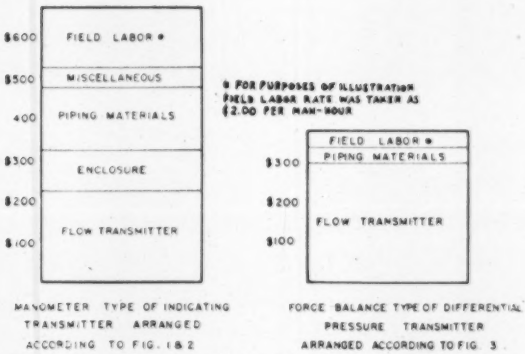


Fig. 4. Comparison of installed costs, low viscosity oil flow control.

a pressure controller which regulates the steam condensing pressure in accordance with an impulse from the temperature controller. Method B is similar to A, except that a further reduction in cost is effected by eliminating the pressure controller and substituting a suitable double diaphragm, or pressure-balanced, control valve. The double diaphragm steam reducing valve admits steam to the tubes of the exchange at a pressure which is proportional to the controlled air pressure from the temperature controller. The controlled variations in the condensing pressure result in corresponding variations in the average condensing temperature, thereby accomplishing regulation of the rate of heat input to the exchanger. These schemes have been used with success in processing units.

Further savings can be realized if an entirely different method of control of heat input to the reboiler or heater is used. For example, the rate of condensate flow can be controlled by means of a temperature controller. Full steam pressure is applied to the tubes, resulting in higher rates of heat transfer at those tubes where steam condenses. When the heat demand of the process is less than the maximum capacity of the heater, the temperature controller causes the control valve in the condensate line to adjust the rate of condensate discharge so that sufficient tubes in the heater are flooded with condensate, thereby reducing the effective heat transfer area of the heater enough to maintain the desired process temperature. This method of temperature control is illustrated in Fig. 12. It consists of a force-balance differential pressure flow transmitter, a simple flow indicator, a remote index set flow controller, a control valve, and auxiliary equipment. These items are light enough to be mounted on a steel plate hung from the condensate line. A weatherproof cover may be provided over the assembly. The meter-connecting tubing from the orifice is routed under the insulation of the main condensate line to prevent freezing. Since the bare condensate line goes through the

Fig. 5. Manometer-type flow transmitter for highly viscous oil.

Fig. 10 shows a photograph of the condensate drainage facilities which were represented diagramatically in Fig. 8. The equipment consists of a condensate receiver, a level controller, a gage glass with lighting and a control valve installation. All of this equipment has to be insulated for operation during cold weather. Steam input control and condensate drainage control such as have been shown in Figs. 8, 9, and 10 have proved to be highly satisfactory. The stabilizing influence of the steam flow controller is usually very beneficial if there are fluctuations in the supply pressure or in the exchanger condensing pressure. However, it is obvious from the foregoing illustrations that this type of control installation is complex and expensive.

In Fig. 11 alternative methods of steam input control are shown diagramatically. In method A economy is effected by eliminating the relatively costly flow controller, and substituting

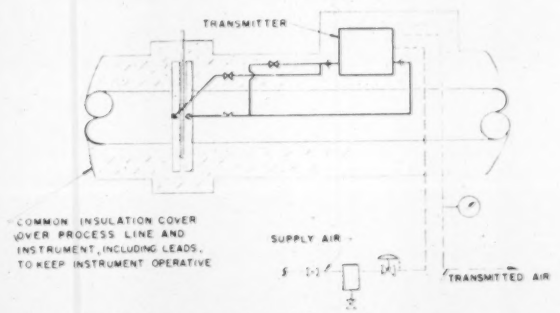

TRANSMITTER
COMMON INSULATION COVER OVER PROCESS LINE AND INSTRUMENT, INCLUDING LEADS, TO KEEP INSTRUMENT OPERATIVE
SUPPLY AIR
TRANSMITTED AIR

Fig. 6. Application of force-balance type differential pressure transmitter to heavy oil service.

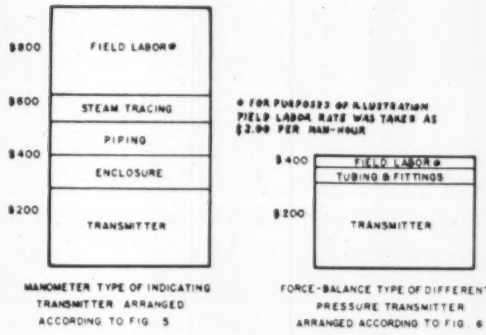


Fig. 7. Comparison of installed costs, highly viscous oil flow control.

housing, the enclosure is heated without additional steam tracing. However, the condensate must be drained out of the system if it is shut down for extended periods in freezing weather.

The flow controller in this method of condensate control tends to prevent excessive loss of live steam into the condensate header at times of high heat demand in the process, when the condensate level drops below the tubes. With regard to pressure stabilization, no additional controls are necessary because the control valve operates with a relatively constant pressure drop between the steam supply pressure and the condensate return header pressure. The method of condensate flow control has its limitations, however. Full steam pressure and temperature are applied to the upper tubes in the exchanger bundle, while a lower tube temperature may result in the bottom tubes which are flooded with condensate. If sufficiently unequal tube expansion occurs in floating-head or fixed tube-sheet types of exchangers, leakage at the tube rolling, or even more serious damage, may result. The expansion difficulty can generally be obviated if hairpin or "U" tubes can be used. Of course, "U" tubes are difficult to clean and replace. From a control response standpoint, it might be mentioned that, although additional tubes are readily exposed by lowering of the condensate level in the bundle at times of increasing heat demand, the rate at which tubes are flooded at times of decreasing heat demand is apt to be quite slow as it is dependent upon the volumetric rate of condensate formation as well as upon the position of the level within the bundle. Further, unless precautions are taken to vent non-condensables such as CO_2, O_2, etc. from the bundle, they tend to accumulate and increase the corrosion rate.

Fig. 13 shows a cost comparison of the conventional steam-flow and condensate-level control method illustrated by Figs. 8, 9, and 10, with the alternative condensate-flow control method which was shown in Fig. 12. The condensate-flow control system is estimated to cost only about one-fourth as much as the more elaborate system. Although the condensate-flow control scheme is not quite as flexible in operation, it can be used at a large saving in applications where the operating disadvantages are not serious.

Fig. 14 shows a commonly used system for fractionator pressure and top temperature control, where the overhead vapor is totally condensed. The tower top temperature is controlled by regulating the rate of reflux returned to the fractionator. This is accomplished by means of a temperature controller directly operating the reflux control valve. A level controller on the reflux drum regulates the discharge of the net overhead product, which is the difference between the total amount of condensed overhead vapor and the amount of reflux returned to the fractionator. The pressure in the tower is controlled by regulating the rate of cooling water flow to the overhead condenser. This fractionator control is generally satisfactory but requires considerable control equipment. In an alternative fractionator overhead control system, illustrated in Fig. 15, the reflux drum is operated full of liquid, and the level is maintained in the condenser to submerge some of the tubes. Tower pressure is thus controlled by varying the condensing surface exposed to the overhead vapors. The cooling water flow rate is adjusted manually to hold the condensate level within the exchanger. The elimination of the reflux-drum level controller and the water control valve usually results in a cost advantage in favor of the alternative control method, if adequate condenser surface is provided. However, the rangeability of the alternative system is limited compared to that of the installation described in Fig. 14.

Some control installations, such as those for flow or level, require regulation of pump discharge rates. Fig. 16 illustrates a method of regulating the speed of a turbine-driven pump by means of a control valve in the steam line to the turbine inlet. Although this method is in use for relatively simple

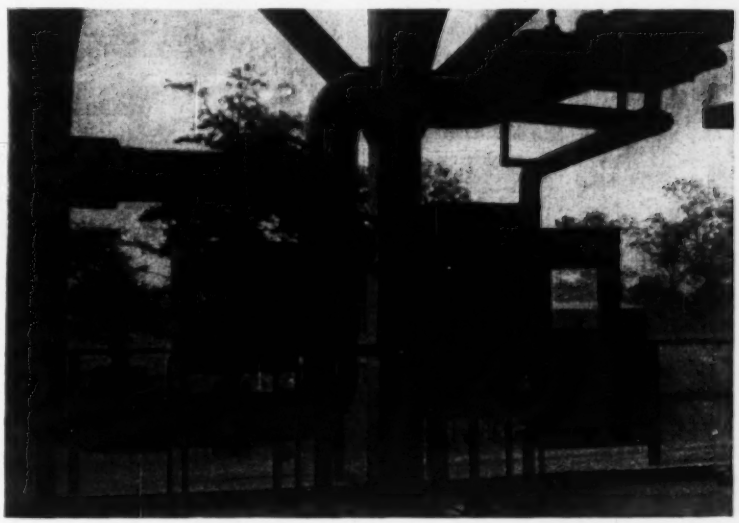


Fig. 9. Steam flow controller for reboiler or steam heater temperature regulation.

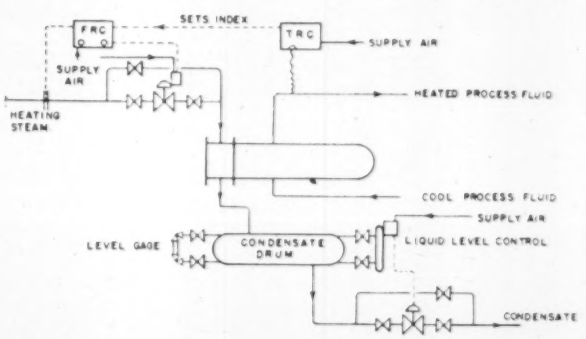
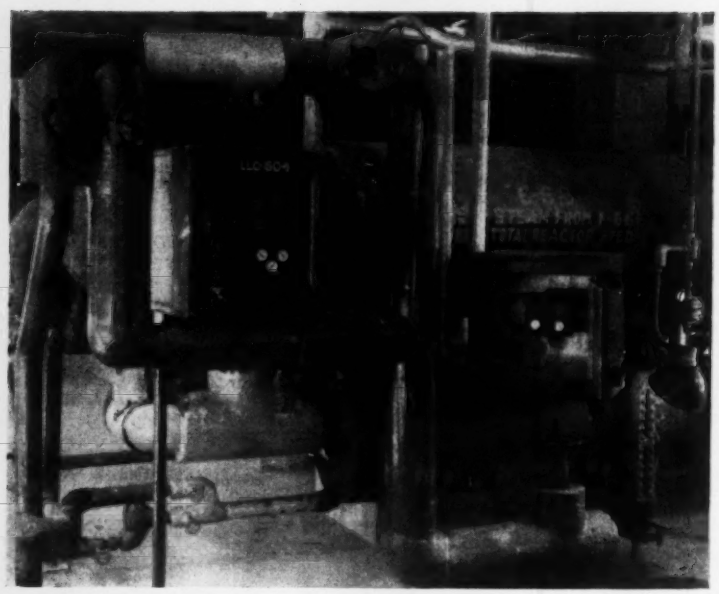


Fig. 8. One method of temperature regulation by steam input control for a reboiler or steam heater.



control, it has a number of disadvantages. Good control response is difficult to obtain. The control valve must be nearly full line size, i.e., relatively large, because it must be sized to control maximum steam flow at minimum pressure drop. The block and by-pass valves around the control valve are relatively large and expensive. However, one block valve and one by-pass valve can be eliminated where a spare pumping unit is available, and where it is feasible to operate the spare in case of failure of the control valve.

Another method of turbine regulation is one utilizing a variable speed governor furnished with the turbine and actuated by a remote controller. Variable speed governors are in use on large turbines, and several designs have recently been developed by manufacturers for small turbines.

Fig. 17 shows a comparison between the installed cost of a pneumatic control valve with blocks and by-passes and the cost of a built-in variable speed governor on the turbine. The comparison is shown for 2- and 4-inch external control installations.

Although the advantages of centralized control by installing important

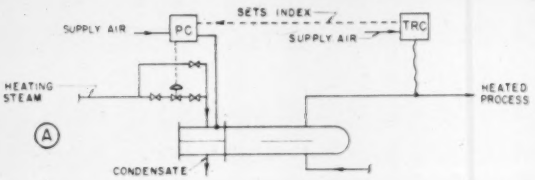


Fig. 10. (Left above) Condensate drainage controls for reboiler or steam heater.

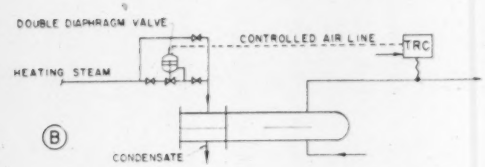


Fig. 11. (Left center) Alternative methods of temperature regulation by steam input control for a reboiler or a steam heater.

Fig. 13. (Below) Comparison of installed costs of steam heater or reboiler controls.

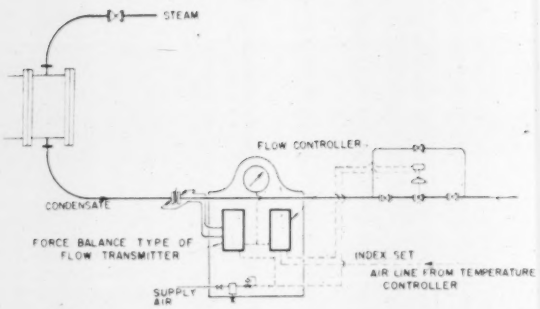
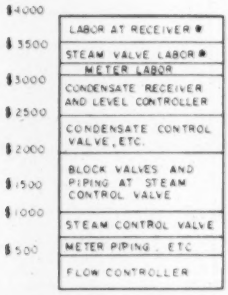


Fig. 12. (Above center) Temperature regulation by condensate flow control from a reboiler or a steam heater.



STEAM INPUT CONTROL IN ACCORDACE WITH FIGURE 8

CONDENSATE FLOW CONTROL IN ACCORDANCE WITH FIGURE 12

Fig. 14. (Right center) Fractionator pressure and top temperature control where the overhead vapor is totally condensed.

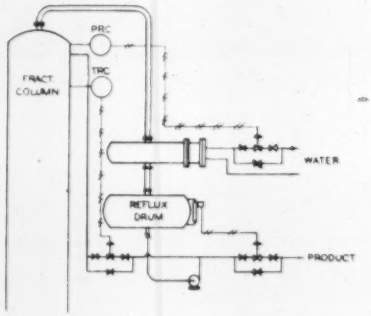
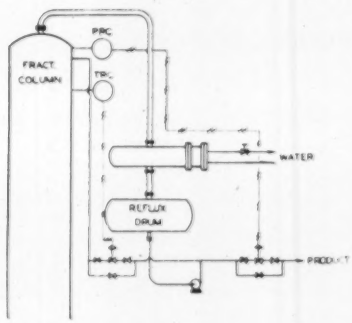


Fig. 15. (Right) Alternative method of fractionator pressure and top temperature control.



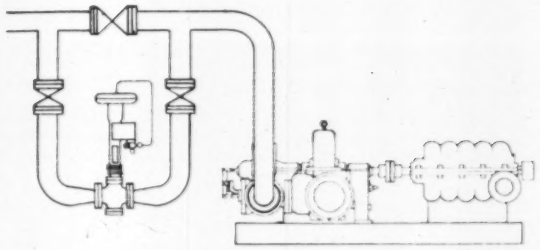


Fig. 16. Regulation of pump discharge by control valve in steam line to turbine.

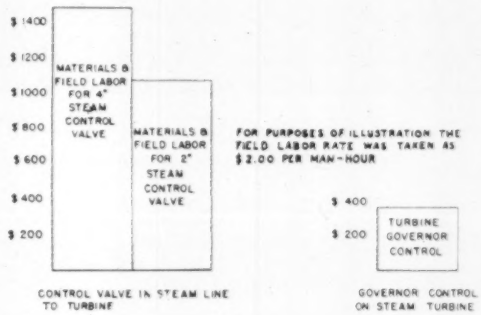

$ 1400
$ 1200
$ 1000
$ 800
$ 600
$ 400
$ 200
MATERIALS & FIELD LABOR FOR 4" STEAM CONTROL VALVE
MATERIALS & FIELD LABOR FOR 2" STEAM CONTROL VALVE
FOR PURPOSES OF ILLUSTRATION THE FIELD LABOR RATE WAS TAKEN AS $2.00 PER MAN-HOUR
$ 400
$ 200
TURBINE GOVERNOR CONTROL
CONTROL VALVE IN STEAM LINE TO TURBINE
GOVERNOR CONTROL ON STEAM TURBINE

Fig. 17. Costs of regulating pump discharge by turbine speed control.

instruments in the main control room of the processing plant are quite well known, it should be recognized that such installations are costly. The centralization of instruments on a control board entails not only the expense of pneumatic transmitters with their enclosures and long transmission lines, but also requires space in the control room. The cost of locating an instrument on the control room panel must be justified by (a) the importance of the function, (b) safety in operation, and (c) operating convenience.

In conclusion, this article has attempted to point out various instrumentation and control practices which are costly, and to point out means for reducing such costs by the use of simplified schemes which utilize modern control equipment.

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ELECTRONICS ENGINEER. GS-11. $5400 per annum.* Position: Group Leader for research, design, development, and operation of electronic devices for use in Telemetering, Doppler, Magnetic Pick-ups, and Guided Missiles. Requirements: Several years of research, lab, and government experience in the fields above.

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ELECTRONICS ENGINEER. GS-11. $5400 per annum.* Position: Metric Electronics, Radar Section. Duties: (1) Supervision of Radar Field Unit. (2) Design and development of electronic equipment. Requirements: Thorough background in radar.

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*Civil Service status not required.

**Examination eligibility required. Examination open Joint Board of Civil Service Examiners, 1030 Green St., Pasadena, Calif.

Toledo Group Joins ISA

The Toledo Instrument Society was officially granted the fifty-first ISA local Section Charter on April 15. This group of 85 or more members will be known as the Toledo Section, ISA. Secretary of the new Section is Mr. Morrison L. Conner, P. O. Box 2 Station A, Toledo, Ohio. A most hearty welcome is extended to the new group.

Section Secretaries, Meeting Data and Programs

AKRON
Fred Appel, 932 Columbia Ct., Barberton, Ohio. Tel: SH 3440
Fourth Tuesday, Meeting at 7:30 P. M., Akron Y.W.C.A.

ALBUQUERQUE
L. J. Paddison, 911 Parkland Circle, Albuquerque, N. M. Tel: 5-1806
First Monday, Meeting at 8:00 P.M., Science Lecture Hall, Univ. of N. M.

ARUBA
K. H. Walker, P. O. Box 389, c/o Lago Oil & Transport Co., Ltd., Aruba, N.W.I.
First Tuesday, Meeting at 7:15 P. M.

ATLANTA
H. Kockritz, Fischer & Porter Co., 84 Peachtree St., Atlanta, Ga. Tel: CY 1269
Fourth Monday, Meeting at 7:45 P.M., Ga. Institute of Technology.

BALTIMORE
George B. Greer, 631 E. 36th St., Baltimore 18, Md. Tel: Chesapeake 6879
Second Friday, Meeting at 8:00 P.M., Engr's. Club of Baltimore.

BATON ROUGE
John Q. Bass, 1517 Longwood Dr., Baton Rouge, La.
Meeting at 7:30 P.M., L.S.U. Geology Bldg.

BOSTON
C. J. Nazzaro, 456 Central Avenue, Milton 87, Mass. Tel: CU 6-2479
Last Wednesday, Dinner at 6:30 P. M., Meeting at 7:00 P.M., Patten's Restaurant.

CALIFORNIA
D. C. Duncan, Helipot Corp., 916 Meridian Ave., S. Pasadena, Calif. Tel: SY 4-8439
Second Wednesday, Dinner at 6:30 P. M. Meeting at 8:00 P. M.
May 2: Sound Slide Film No. 3.

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H. F. Lange, 2101 W. Glen Avenue, Peoria 5, Ill. Tel: Peoria 5-4516
First Wednesday, Dinner at 6:30 P.M., Meeting at 7:30 P.M.

CENTRAL INDIANA
H. F. Coffey, 4029 N. Temple Ave., Indianapolis, Ind. Tel: HU 5832
First Tuesday, Meeting at 7:30 P. M.

CHARLESTON
Clayton A. Williams, 303 E. 9th St., Belle, W. Va. Tel: 927871
First Monday, Dinner at 6:30 P.M., Meeting at 8:00 P.M., Kanawha Hotel.

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Floyd E. Ertaman, Rm. 1420 Fisher Bldg., 343 S. Dearborn St., Chicago, Ill. Tel: WE 9-0686
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A. H. Staud, 209-B Entwistle, USNOTS, China Lake, Calif. Tel: 77882
Fourth Thursday, Meeting at 8:00 P.M., Michelson Lab, USNOTS.

CINCINNATI
Edward H. Muhleisen, 320 Durrell Ave., Cincinnati 15, Ohio. Tel: PO 1168
First Monday, Meeting at 8:00 P.M., Eng'r. Society Hqs.

CLEVELAND
R. M. Woodside, 332 Oakmoor Rd., Bay Village, Ohio. Tel: TR 1-4405
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Orval Linebrink, c/o Battelle Memorial Institute, 505 King Ave., Columbus, Ohio. Tel: UN 3191, Ex. 248
Third Thursday, Battelle Auditorium
May 18: "Radiation Pyrometer," by John R. Green, Brown Instr. Div. Minneapolis-Honeywell Reg. Co.
June 15. "Electronic Instrumentation," Dr. Francis Todd, Battelle Institute.

CUMBERLAND
Clyde Babst, 225 Cecilia St., Cumberland, Md. Tel: 583-W
Tuesday after Fourth Monday, Dinner at 6:30 P.M., Meeting at 8:00 P.M., Algonquin Hotel.

DETROIT
Seymour Sterling, 13331 Linwood, Detroit, Mich. Tel: Tyler 5-1707
Second Wednesday, Meeting at 8:00 P.M., Rackham Bldg.

EASTERN NEW YORK
W. R. McKegg, c/o Gen. Engrg. & Consulting Lab., G. E. Co., Schenectady, N. Y.
First Tuesday, Dinner at 6:30 P.M., Meeting at 8:00 P.M.

GULF COAST
W. N. Sloan, E. I. Du Pont de Nemours & Co., Orange, Texas. Tel: 8411 Ext. 444
Third Tuesday. Meeting at 7:30 P.M., Lamar College.

HOUSTON
Edward J. Byrne, 2123 Travis St., Houston, Texas. Tel. CH 2511
Last Monday, Meeting at 8:00 P.M., Engineers Club.

KANSAS CITY
L. E. Oberhelman, Standard Oil Co., Sugar Creek, Mo. Tel: MU 1227
First Tuesday, Meeting at 7:30 P.M., Univ. of Kansas City.

LOUISVILLE
H. C. Scherffius, 980 Palatka Rd., Louisville 8, Ky. Tel: Franklin 1265
Fourth Tuesday, Meeting at 8:00 P.M., Seagram Auditorium.

MONTREAL
S. J. Mizuhara, 1075 Allard, Verdun, Quebec, Canada. Tel: TR 3252
Last Monday, Meeting at 8:00 P.M. Mechanics' Institute.

NEW JERSEY
W. D. Archibald, 605 Westminster Ave., Elizabeth 3, N. J. Tel: Elizabeth 2-5529
First Tuesday, Dinner at 6:00 P. M. Meeting at 8:00 P.M., Essex House.
June 6, "Users Requirements For Control Valves," W. H. Shellenberger, Std. Oil Dev. Co.

NEW ORLEANS
W. H. Haney, 2927 Music Avenue, New Orleans, La.
No Regular Date, Meeting at 8:00 P.M.

NEW YORK
Norman J. Cherry, P. O. Box 608, Merrick, L. I., N. Y. Tel: Freeport 9-4127
Last Monday, Meeting at 7:30 P.M., Statler Hotel.

NIAGARA FRONTIER
Mrs. James L. Martin, 697 Potomac Ave., Buffalo 9, N. Y. Tel: GR 1450
Fourth Monday, Dinner at 6:15 P.M., Meeting at 8:00 P.M., Institute of Arts and Sciences, Buffalo.
May 22, "How to Select a Control Valve," B. A. Irwin, Hammel-Dahl Co.

NORTH TEXAS
R. E. Byers, 6000 Lemmon Ave., Dallas 9, Texas

NORTHERN CALIFORNIA
M. A. Dimmick, 5607 Alta Punta, El Cerrito, Calif. Tel: Be 5-1095
Third Monday, Meeting at 7:30 P.M., Angelo's, Emeryville.

NORTHERN INDIANA
J. Baum Beckman, 547 N. Waller Ave., Chicago 44, Ill. Tel: ES 8-7776
Third Wednesday. Dinner at 6:30 P.M., Meeting at 7:30 P.M., Gary Y.M.C.A.

OAK RIDGE
John H. Clark, 230 Canton Hall, Oak Ridge, Tenn. Tel: 5-9142
First Wednesday. Dinner at 6:30 P.M., Meeting at 7:30 P.M., Oak Terrace.
June 6, "Condensed Controls," A. Sperry.

ONTARIO
John W. Huether, 311 Southerland Dr., Leaside, Ontario, Canada. Tel: HU-7114
Third Thursday. Dinner at 6:45 P. M. Meeting at 8:15 P. M. Friendship Hall, College St. United Church, Toronto

PANHANDLE
R. E. Harris, 228 Maya Bldg., Amarillo, Texas. Tel.: 31434.

PHILADELPHIA
C. W. Wood, 6908 Market St., Upper Darby, Pa. Tel: Clearbrook 9-3959
Third Wednesday, Meeting at 8:00 P.M., Bellvue Stratford Hotel.
May 17, "Industrial Television," Walter L. Lawrence, RCA-Victor Div., RCA.

PITTSBURGH
Miss Louise Suckfield, P.O. Box 2038 Pittsburgh 30, Pa. Tel: HI 1-6880
Fourth Monday, Dinner at 6:30 P.M., Meeting at 8:00 P.M., Roosevelt Hotel.
May 22, "The Bethlehem Flow Tube, Its Theory, Design and Development," V. Gentile, Jr., Bethlehem Fdy. & Mach Co.
Pittsburgh Inspection & Gaging Committee, Second Tuesday, Meeting at 8:00 P.M. Wm. Penn Hotel. Tel: CE 1-5621
May 9: "Inspection-Gaging and Statistics Quality Control," Arthur S. Marthens, U. S. Navy Inspection Service.

PRESQUE ISLE
Edwin P. Schuwerk, 445½ Halley St., L. P. Erie, Pa. Tel: 2-3349
Fourth Tuesday, Meeting at 8:00 P.M., G. E. Community Center, East Lake Rd.
May 23: "Pneumatic Control Instruments and Computing Devices," Mr. Wiley, American Meter Company.

RICHLAND
M. T. Slind, M-6, Rm. 107, Richland Washington Tel: 4615-R
Second Wednesday, Meeting at 7:30 P.M. American Legion Hall.

ROCHESTER
R. C. Schwarz, Jr., 1201 Granite Bldg. Rochester 4, N. Y. Tel: Monroe 4610R
Fourth Tuesday, Meeting at 8:00 P.M., Univ. of Rochester, Physics Lecture Hall.
May 22, Social Program

SARNIA
Fred T. Yorke, P. O. Box 213, Point Edward, Ontario, Canada. Tel. 2363J
Second Friday, Meeting at 8:00 P.M., Moose Hall.

SOUTH BEND
Sam M. Rouse, 436 Moccasin Ave., Buchanan, Mich. Tel: 678
First Thursday. Meeting at 8:00 P.M., Engineers Club, Hotel La Salle, South Bend.

SOUTH MICHIGAN
Larry DeHaan, 1117 Cobb Ave., Kalamazoo, Mich. Tel: 2-0385
Fourth Wednesday, Dinner at 6:30 P.M. Meeting at 8:00 P.M., Chicken Charlie's, Kalamazoo.

SOUTH TEXAS
H. C. Givens, La Gloria Corp., P.O. 637, Falfurrias, Texas. Tel: 122-W
First Thursday. Meeting at 7:30 P.M., Garner Aircraft Instrument School.

ST. LOUIS
W. G. Lee, 4710 Delor St., St. Louis 16, Mo. Tel: FL 8516
First Wednesday, Meeting at 8:00 P.M., Engineers' Club of St. Louis.

TOLEDO
Morrison L. Conner, Toledo Edison, 925½ Sherman St., Toledo, Ohio.

TENNESSEE
N. M. Taylor, 16 Edgewood, Kingsport, Tenn. Tel: 3338J
No definite night, Dinner at 6:45 P. M., Meeting at 8:00 P.M.

TULSA
C. R. Horton, 8211 E. 7th, Tulsa, Oklahoma Tel: 92-1434
First Monday, Meeting at 6:45 P.M., Engineering Bldg., Tulsa Univ.

TWIN CITIES
Alden Hine, c/o Giesika & Pinkney, 552 Plymouth Bldg., 6th & Hennepin Ave., Minneapolis 2, Minn. Tel: Whittier 6420
Fourth Tuesday, Dinner at 6:30 P.M. Coffman Memorial Union. U. of Minn.
May 23, "Instruments in Weather Forecasting," S. F. Spilhaus, U. of Minn.

WASHINGTON
Raymond E. Miller, 20-224 Naval Ord. Lab. White Oak, Md. Tel: JU 7-6742
Third Monday, Meeting at 8:00 P.M., P. E. P. Co. Auditorium.

WAYNE COUNTY
Robert Karr, 2455 Biddle Ave., Wyandotte, Michigan. Tel: 0167J
Third Monday, Dinner at 6:30 P.M., Meeting at 8:30 P.M., Poremba Hotel, Ecorse, Mich.

WILMINGTON
Dean Valentine, 34 N. Hill Drive, West Chester, Pa. Tel: 0293W
Third Tuesday, Meeting at 8:00 P.M. Harlan Public School, Wilm.

JOURNAL of the Southern California Meter Association

President: R. Frank Fields — Auditor: John T. H. Morris
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Application *of the* Fundamental Gas Laws *to* Orifice Metering

By EDGAR VALBY, Richfield Oil Co.*

IN the measurement of a gas by any of the various methods available, for example the orifice meter or the displacement meter, three variables are used to express the amount of gas being considered: pressure, volume and temperature. The behavior of a gas, when one of these variables has been changed, has been studied over many years, and various investigators have developed certain laws of behavior known as Fundamental Gas Laws. However, these are only statements of behavior and do not explain why the gas acts the way it does. A few brief statements as to the physical state of gases will bring out the reasons why.

All matter is composed of molecules, that is, the smallest units to which a substance can be divided and yet retain its identity. These molecules are in constant vibration even when in a solid or liquid state. Their speed and length of travel depends upon the temperature, and upon the state in which the substance exists; say a solid, liquid or gas. In a solid or liquid state the molecules do not have the speed to overcome the cohesive forces between the molecules. However, in gases, the speed of the molecules is greater than the attraction for one another and the molecules are far apart in comparison to their diameters. All gases can be liquefied at suitably low temperatures and high enough pressure. Gases at ordinary temperatures and pressures are to be considered as the superheated vapors of low-boiling-point compounds. Vapors are the gaseous state of compounds near their boiling point and can account for any deviation from the fundamental gas laws.

In a gas the molecules move about with a great speed and it is the constant pounding of these molecules upon the walls of the containing vessel that we measure as pressure. Temperature increases the speed of the molecules and the increased speed raises the pressure of the gas in the confining vessels.

Since the molecular motion theory can explain the reaction of gases to pressure and temperature, it follows that this theory can give a basis for the measurement of these conditions. This starting point is that point where there is no molecular activity at all: for pressure a perfect vacuum, and for temperature absolute zero. For the measurement of pressure in absolute units it is necessary to determine the atmospheric pressure as the atmosphere surrounds all things on earth. The conventional method is to read a mercury barometer. This device is made by filling a glass tube about 34 inches long, sealed at one end, with mercury and placing it in an inverted position in a reservoir of mercury. Necessary precautions are taken so that no water vapor or air is trapped in the tube which would affect the degree of vacuum in the barometer. By means of a suitable scale, the height to which the mercury stands is measured. The absolute pressure, then, within a container is the gage pressure plus the barometric pressure, both of course in the same units. For example we have a pipe line that has 20 pounds per square inch gage and a barometer reading of 14.7 lbs., the absolute pressure would then be 34.7 lbs. per square inch (34.7 psia.).

The point of no molecular activity on the temperature scale gives the zero point for absolute temperature. This point, known as absolute zero, has been determined by several ways to be −459.6 F. (or −460 F. as used in most calculations). One method of determining this value has been to measure the contraction in volume of hydrogen at constant pressure in a container filled at 0 F. when the temperature is lowered one degree F. This contraction has been found to be 1/459.6 of the original volume. If the contraction is measured at other lower temperatures, the absolute zero by extrapolation would be found to be the above value. The absolute temperature can then be found by adding 460 to the observed thermometer reading. Since the standard cubic foot of gas measurement for California has been defined at 14.73 lbs. per sq. in. and 60 F., these are in absolute units: 14.73 psia. and 520 F.

Now as to the fundamental gas laws. The relationship between pressure and volume was discovered by Boyle, an English scientist, in 1600. He found that the volume occupied by a given weight of gas was decreased to one-half of the original volume when the pressure was doubled, with the temperature kept constant. In other words, if the temperature is kept constant the volume will vary inversely as the absolute pressure. Mathematically this is expressed by the equation:

$$P_1V_1 = P_2V_2$$

where P_1V_1 is the pressure and volume under one set of conditions and P_2V_2 under the second set of conditions.

For example, what is the volume at 40 psia. at 60 F. of 4000 cubic feet initially at 20 psia. and 60 F.? The answer is found by the expression:

$$V_2 = \frac{P_1V_1}{P_2} = \frac{4000 \times 20}{40} = 2000 \text{ cu. ft.}$$

Charles' law, also discovered by others, states that the temperature-volume relationship of a given weight of gas, pressure being constant, is expressed by the statement that its volume varies directly with the temperature. Again mathematically it is expressed by:

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

Again, for example, the above gas was heated to 520 F. or 1040 abs. at 40 psia., what is the new volume?

$$\frac{2000 \times 1040}{(60 + 460)} = 4000 \text{ cu. ft.}$$

Both of these laws can be combined

June meeting: Thursday the 15th, Rio Hondo Country Club, Downey, Calif. Dinner at 6:30; meeting 8 sharp.

Features: Fourteenth Annual Low Jinks; and Election of Officers.

—THERON S. CODY
Publicity Chairman

* Read by James E. Adams at meeting of S.M.A. March 16, 1950.

into the one law, that of the perfect Gas Law.

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} = \text{a constant.}$$

By means of these equations and the combined form, the measurement of the volume of any gas at moderate pressures and temperatures can be converted to the standard cubic foot at 14.73 psia. and 60 F.

The perfect gas law can also be expressed in the form

$$P\,V = n\,R\,T.$$

where n = the pounds of gas and R the gas constant for the gas in question which is $1544/m$ when m is the molecular weight of the gas and 1544 the universal gas constant. P in this expression is in pounds per square inch absolute. Usually the expression is reduced to the form

$$P\,V = 10.72\,N\,T$$

where P is in pounds per sq. in. abs. V is in cu. ft., N is the pound mols, and T the absolute temperature. A pound mol of any substance, gas, liquid or solid is a quantity whose weight in pounds is the same as its molecular weight. This holds true for all true gases.

It was early realized that all of the gases are not perfect gases and the additional factor Z (deviation factor) has been added to the above expression:

$$P\,V = 10.72\,ZNT$$

This deviation factor Z can only be determined experimentally and is of great use in the measurement of gases at high pressures.

The pound mol is used in many chemical calculations and can be used to calculate the density or weight of 1 cu. ft. of any gas at standard conditions. First of all it is necessary to determine the volume of a pound mol of gas at our standard conditions of 14.73 psia. and 60 F. Solving the perfect gas law for V for 1 pound mol of gas.

$$V = \frac{1 \times 10.72 \times 520}{14.73} = 378.4$$

We find that V equals 378.4 cu. ft. at 14.73 psia. and 60 F., or, as used in most calculations 378 cu. ft. Then the density of any gas can be found by dividing the molecular weight in lbs. by 378. For example, oxygen has a molecular weight of 32.00, therefore, its density would be 0.0846 lbs. per cu. ft. at 14.73 psia. and 60 F.

Air is composed of approximately 79 percent nitrogen and 21 percent oxygen with small traces of carbon dioxide and the rare gases, which gives it a molecular weight of 29.0. If the specific gravity of a gas to air is known, its molecular weight is $29.0 \times G =$ molecular weight of the gas, for example:

$$29.0 \times 0.60 = 17.4$$

The determined density of air is 0.07654 lbs. per cu. ft. at 14.73 psia. and 60 F.

A further use of the basic gas laws is to calculate the effect of changes in pressure or temperature upon the density of any gas. Gravity, expressed by the use of the letter G, or more properly the specific gravity, is the ratio of the weight of one standard cu. ft. of the gas to the weight of one standard cu. ft. of air being used as the base. Therefore, the density of the gas would be the weight of 1 cu. ft. of air multiplied by its specific gravity.

The combined gas laws are used to compute the changes in density by the following expression:

$$d_2 = \frac{d_1 \times 520 \times P_2}{T_2 \times 14.73}$$

For example what is the density of a gas at 80 F. that has a gravity of 0.75 at a constant pressure of 14.73 psia.?

$$d_{80} = \frac{0.07654 \times 0.75 \times 520 \times 14.73}{(460 + 80) \times 14.73}$$

$$= 0.0574 \text{ lbs. per cu. ft.}$$

If, in addition, the pressure was increased to 15 lbs. gage, the density would be d_{80} and 15 psig.:

$$= \frac{0.07654 \times 0.75 \times 520 \times (15+14.73)}{540 \times 14.73}$$

$$= 0.1159 \text{ lbs. per cu. ft.}$$

Since it is known that the gases deviate from the perfect gas law, and if for a particular case the deviation factor Z has been determined or estimated by one of several methods published at various times, the density of a gas can be calculated by means of the perfect gas law:

$$PV = ZNRT$$

$$\text{from which density} = \frac{1}{V} = \frac{P}{ZNRT}$$

Here again we may take the previous example where the gas has a gravity of 0.60 or a molecular weight of 17.4 and a Z factor of 0.725 for a pressure of 1900 psia. and 80 F. In this case we will use 1 lb. of the gas to calculate the density:

$$\text{Density} = \frac{1900}{0.725 \times (1/17.4) \times 10.72 \times 540}$$

$$= 7.877 \text{ lbs. per cu. ft.}$$

In conclusion, the fundamental gas laws are a very useful tool to make computations as to what happens to a given weight of gas when the pressure and temperature are changed, and with the introduction of the deviation factor we are able to apply them to problems involving the measurement of gas at any pressure and temperature.

Fundamentals *of* Orifice Meter Measurement

By J. B. TAYLOR, Jr., Signal Oil and Gas Co.*

SPEAKING of fundamentals, the first point to explore is to learn what makes an orifice meter. Well, an old-time hour-glass is an example of the basic operating principle of the orifice meter. It was essentially not a recording type, but it measured time by the same elements that constitute an orifice meter. The basic elements of an orifice meter are a conduit or pipe and a means of restricting the fluid flow.

The orifice is the most commonly used means of restricting the flow. In 1797, Venturi, an Italian physicist, experimented with orifices; and some of the present-day types of modified orifices are related to his work. The Venturi meter is a special type of orifice and finds usefulness in many places. Orifices may be of different design. There are sharp-edged, round-edged or beveled-edged orifices and all are used for the purpose of restricting the flow to create a measurable change of energy.

It was not until 1903, or later, that T. R. Weymouth did most of his experimental work on orifice meters. His principal purpose was to develop a means of measuring gas in closed conduits and particularly the larger volumes of gas. His original measurements were made by instantaneous observations of the reading of a water column.

The water column served well for tests, but was unsatisfactory for use in the later type meters with recorders. However, Mr. Weymouth did set up recommendations for orifice meter measurement that have aided in developing and maintaining standards and also duplicable installations. Some of his early recommendations include that the orifice thickness be limited to one-eighth of the diameter of the orifice, that there be ten pipe diameters of straight run of unobstructed pipe upstream and down stream from the orifice and also that the differential in inches of water be kept less than the static pressure in pounds per square inch absolute. These recommendations cover the basic installations today.

The present orifice meter is simply a standardized means of restricting or impeding flow. If we place any impedi-

*Read by James E. Adams at meeting of SCMA, March 16, 1950.

ment in a gas line we will create a pressure drop, and the amount of pressure drop will increase with the rate of the flow. Conversely, there will be no pressure drop at zero flow rate.

Experimentally, it has been found that, within reasonable accuracy, thin, sharp, square-edged orifice plates of a given diameter would create the same pressure drop at the same rate of flow. In such a manner, this type of orifice plate has been standardized and further specified. Other physical requirements of the orifice meter have been specified largely to standardize all the elements of the meter. Thus, a tolerance of accuracy may be established and meter runs may be duplicated with comparable results.

Throughout the experimental development, different investigators were responsible for certain changes. Mr. Weymouth developed the commonly-used flange type meter set-up with the pressure taps at the orifice flanges. Later Hickstein and Fisher developed the pipe-tap connections, with the pressure taps 2½ diameters upstream and 8 diameters downstream of the orifice. The pipe taps avoided the impact effects at the upstream face of the orifice and away from the pressure recovery effects downstream.

The empirical coefficients developed by the same investigators were used without question until 1924. At that time the American Gas Association initiated a ten-year study of the sharp, thin plate, square-edged orifices. The results of this investigation are the present coefficients now in use and the standard requirements for orifice meter installations, which were published as Report No. 2 of the Gas Measurement Committee of the AGA. In this report are complete specifications for the orifice plate, and the meter run and also all the coefficient data relative to gas measurement. This Report, edited to meet with California practice, is published as the latest coefficient data by the Southern California Meter Association and the California Natural Gasoline Association.

Our next problem is to learn what happens in an orifice meter. When measuring gases we know that we have a pressure that is related to absolute pressure, and that when a flow exists there is a difference of pressure upstream and downstream of the orifice that we call the differential pressure. To determine the actual rate of flow, it is necessary to make certain calculations using the values of the absolute pressure and differential pressure.

Normally, our problem is to apply a coefficient or multiplying factor to the square root of the product of the absolute pressure and the differential readings, when using direct-reading charts.

However, the meter chart and readings are the result of what occurs in an orifice meter. Actually, our orifice meter is recording a change in the energy relations of the gas as it passes through the orifice plate. The differential pressure across the orifice means that the pressure downstream of the orifice plate is less than the upstream pressure. Therefore, the volume occupied by the gas downstream of the orifice is greater than the volume of the gas upstream of the orifice, owing to this reduction of pressure. For this same reason, the velocity downstream of the orifice is higher than the velocity of the gas upstream. Now all of these changes of conditions make it possible to derive an equation which relates the changes of energy of the fluid.

So, the basic coefficient is an equation of energy that measures the work done in passing the gas through the orifice. Since work involves horsepower, our measurement is in terms of pounds of gas moving through feet of pipe a minute. Horsepower is foot pounds of work done in a certain time. Now that we have related our measurement to feet per second (velocity) and pounds (weight), it is possible to explain the performance of a recorder of an orifice meter in relation to the pipe-line flow.

For an example, air is flowing through an orifice meter at a rate of one pound per minute, the upstream pressure is slightly above atmospheric and the differential pressure reading is 5 inches of water. This condition of flow will provide the energy for a certain amount of work. The 10 pounds of air we will estimate to equal about 240 cubic feet at atmospheric pressure. Therefore its velocity in a 6-inch standard pipe under 15 pounds absolute pressure would be about 48 feet per minute.

Now, let us see what would happen if, instead of air, we use a gas of 0.75 specific gravity. This means that 7.5 pounds of this gas will equal 240 cubic feet of volume at atmospheric presure. And since this volume of gas passing through the orifice in the same period of time will not do the same amount of work as the air and create the same differential, a greater volume of gas flowing at a higher velocity would be necessary to create the same differential pressure reading and do the equivalent work done by the air.

By further contrast, a heavy vapor of 1.5 specific gravity would weigh 15 pounds for the same 240 cubic feet at atmospheric conditions. Therefore, this vapor to produce the same amount of work as the air would require less in volume and consequently a lower velocity to produce the same differential reading.

By these comparisons, we note the value of the specific gravity or density of the gas and the importance of the factor in the flow formula.

The density of the gas may be increased through additional pressure and thus forcing a given weight of gas to occupy less volume. Under higher pressures more gas is packed in a given volume and the weight per cubic foot of the gas is increased.

The effect of higher pressure, then, is to do the same work with less velocity. This is comparable to the vapor of 1.5 specific gravity. For instance, a gas with 0.75 specific gravity (about equal to 0.056 pounds per cubic foot at atmospheric conditions) would, under two atmospheres pressure, 30 pounds per square inch absolute, have a density of 0.112 pounds per cubic foot. Air at atmospheric pressure weighs about 0.076 pounds per cubic foot. Therefore this gas of 0.75 specific gravity under 30 psia. pressure with any velocity will produce the same differential as a vapor of 1.5 specific gravity under atmospheric pressure flowing with the same velocity.

Temperature alters the density of the gas in the same manner as pressure but to a much less degree. A standard cubic foot of gas at 60 F., of 0.75 specific gravity and 0.056 pounds per cubic foot when heated to 120 F. will occupy a space of 1.115 cu. ft. and have a density of 0.502 pounds per cubic foot. Therefore an increase of temperature will increase the velocity of the gas to maintain the same differential.

Now that the orifice meter performance has been related to work (velocity and weight), it is necessary to study the coefficient to find how the volume is corrected for these factors. The basic formula for orifice meter measurement from the energy relations is:

$$Q = 19.64\ E d^2\ \sqrt{(2gH)}$$

This formula corrected for gas measurement by applying the proper factors for the quantity, H (head in feet) to produce the h (head in inches of water differential) at flow conditions:

$$H = \frac{h}{12} \times \frac{62.37}{0.08073 \times G} \times \frac{14.7}{P} \times T$$

Q = Rate of flow in cubic feet per hour.

E = Efficiency, related primarily to d/D ratio and experimentally determined.

Corrected formula:

$$Q = 218.44\ E d^2 \frac{P}{P_B} \times \frac{Tb}{T} \sqrt{\frac{hT}{PG}}$$

In the above formula, the expression $\sqrt{(hT/PG)}$ represents the effect upon measurement of the individual factors on the velocity of the flowing gas.

The expression (P/P_B) (Tb/T) represents the effect upon measurement of the gas flows, by which the flow at line conditions is reduced to standard conditions.

The factor d^2 represents the relationship of the orifice size to the volume of flow.

The above factors represent the basic formula for orifice meter measurement. By extensive experimental investigation other factors have been found to influence the results.

One of these is the viscosity of the gas being metered. Since Reynolds was one of the early investigators in velocity and characteristics of pipe-line flow, this meter factor is known as the Reynolds number factor.

Another factor is known as the expansion factor. It was mentioned earlier that there was a decrease of pressure to produce the differential flow pressure that causes the gas downstream of the orifice to expand and be less dense than the gas upstream of the orifice plate. The density of the gas either up-

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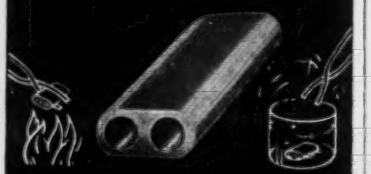

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stream or downstream is not the true density of the gas passing through the orifice. In cases of high-pressure gas measurement or where the differential pressure is a small proportion to the actual static pressure, this expansion is small and the correction factor is consequently of minor importance. Under high-vacuum conditions of measurement, this expansion is more real and in extreme cases may amount to large percentage factors. An example may be assumed at 26 in. mercury vacuum. This is 54.8 in. water absolute pressure. If this were downstream pressure and a differential of 10 in. water existed across the orifice plate a change of the gas from 64.8 in. to 54.8 in. would cause a change of 18.3 percent in the density of the gas.

The last factor that is discussed here is the supercompressibility factor. This factor corrects for the deviation of our natural gases to the laws of ideal gases. The laws of perfect gases state that the density of a gas is inversely proportional to the absolute temperature and directly proportional to the absolute pressure. This deviation has been found experimentally to vary with the different gases over the range of operating conditions. This variation differs with the composition of the gas as well as pressures and temperatures.

Fundamentally, the orifice meter is an instrument of sound engineering principle. Properly installed and operated, it will give service and accurate results.

Manufacturers' New Literature

In this department we report new literature pertaining to Instrumentation, received from the manufacturers. We urge readers to request ONLY those bulletins which will be of value to them. Use the Postage-free Order Card on Page 523.

S-254 "THE GENERAL RADIO EXPERIMENTER." 8-page Vol. 24, No. 10 issue of this house organ features articles on maker's "Type 1021-A" standard signal generator for frequencies between 50 and 920 Mc., and "Type 1000-P6" crystal-diode modulator for video frequencies; lists specifications for each.—General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass.

S-255 COMBUSTION CONTROL. 12-page pictorial bulletin. "How Automatic Combustion Control Comes into Being," describes manufacture of maker's automatic combustion control equipment, from blueprint to shipment.—The Hays Corp., Michigan City, Ind.

S-256 "PERKIN-ELMER INSTRUMENT NEWS. 8-page Vol. 1, No. 2 issue of this house organ features article titled "Research in Clinical Diagnosis Highlights Expanding Use of Electrophoresis Apparatus," and other articles on use of optical instrumentation in research, material analysis and production.—The Perkin-Elmer Corp., Glenbrook, Conn.

S-257 "S-L INSTRUMENT NOTES." 4-page No. 13 issue of this house organ features article titled "The Mass Effect in Fluid Damping"; also illustrates and describes maker's "Model D4" dynamometer.—Statham Labs, Inc., 9328 Santa Monica Blvd., Beverly Hills, Calif.

S-258 POWER SUPPLIES. 2-page bulletin illustrates and describes maker's "Models 1110, 1110-A" regulated power supplies; covers features, specifications.—Furst Electronics, 12 S. Jefferson St., Chicago 6, Ill.

S-259 RADIOACTIVITY COUNTERS, SHIELDS. 4-page bulletin describes and illustrates maker's flow Geiger counters, radiation shielding, sample carrier, etc.; list features, specifications.—Radiation Counter Laboratories, Inc., 1844 W. 21st St., Chicago 8, Ill.

S-260 BEARING ASSEMBLY TOOLS. 4-page bulletin describes and illustrates maker's tools for placing or removing ball bearings; lists features, sizes, prices.—Nestor Engineering Co., 764 Palisade Ave., Teaneck, N. J.

S-261 ANALOG COMPUTER. 2-page bulletin illustrates and describes maker's "Analog Computor," computor components, illustrated responses; features and specifications listed—George A. Philbrick Researches, Inc., 230 Congress St., Boston, Mass.

S-262 SURVEYING ALTIMETERS. 8-page bulletin describes and illustrates maker's "SA" series of surveying altimeters; covers range, dimensions, features and specifications.—American Paulin System, 1847 S. Flower St., Los Angeles 15, Calif.

S-263 "CHLORINATION TOPICS." 8-page Vol. 4, No. 1 issue of this house organ features articles on chlorination in treatment and control of industrial wastes; contains feature "Current Literature Review."—Wallace & Tiernan, Newark 1, N. J.

S-264 "hp JOURNAL." 4-page Vol. 1, No. 7 issue of this house organ features article on maker's 10-500 Mc AM Signal Generator.—Hewlett-Packard Co., 395 Page Mill Rd., Palo Alto, Calif.

S-265 "THE PITTSBURGH EQUITABLE WATER JOURNAL." 20-page Vol. 34, No. 1 issue of this house organ features articles titled "New York City's Water Problem," "Surveying Steel Plant Wastes," and others.—Pittsburgh Equitable Meter Div., Rockwell Mfg. Co., 400 N. Lexington Ave., Pittsburgh 8, Pa.

S-266 CENTRIFUGAL CONTACTORS. 6-page bulletin illustrates and describes maker's centrifugal contractors for liquid-liquid systems and liquids containing solids; covers uses, specifications, features, advantages.—Podbielniak, Inc., 341 E. Ohio St., Chicago 11, Ill.

S-267 PRECISION LEVEL. 4-page Circular 472-1 illustrates and describes maker's 15-inch precision level; covers advantages, uses.—Pratt & Whitney, Div. Niles-Bement-Pond Co., West Hartford 1, Conn.

S-268 STOP WATCHES. 4-page bulletin illustrates and describes supplier's stop watches; lists prices.—Compass Instrument & Optical Co., 268 Fourth Ave., New York 10, N. Y.

S-269 "CEC RECORDINGS." 12-page Vol. 4, No. 1 issue of this house organ features articles on study of ferromagnetic materials, on recording galvanometers, and on maker's "Telereader" for measuring, analyzing, and tabulating oscillographic records data; also discusses maker's torsional vibration pickup and other equipment.—Consolidated Engineering Corp., 620 N. Lake Ave., Pasadena 4, Calif.

S-270 "CHROMALOX NEWS." 4-page No. 40 issue of this house organ features article titled "Degreasing Costs Slashed with Conveyorized Electric Infrared Oven"; also contains items on

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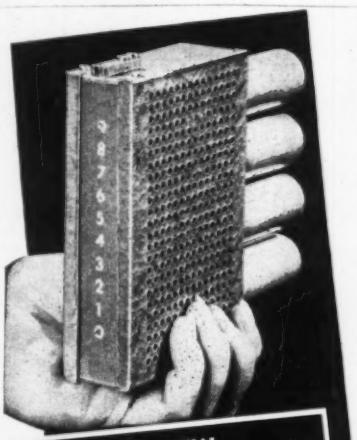

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use of electric heat in various applications.—Edwin L. Wiegand Co., 7500 Thomas Blvd., Pittsburgh 8, Pa.

S-271 HEATING SYSTEMS. 16-page Catalog 76 illustrates and describes maker's vapor and vacuum heating systems; covers radiator valves, thermostatic traps, float and thermostatic traps, condensators, proportionator systems.—Barnes & Jones, Inc., 128 Brookside Ave., Jamaica Plain 30, Boston, Mass.

S-272 METAL DETECTOR. 4-page bulletin describes and illustrates maker's "Model 711" metal detector; covers applications, features, performance data.—The Detectron Co., 5637 Cahuenga Blvd., No. Hollywood, Calif.

S-273 FEEDER-WEIGHER CONVEYOR. 6-page Bulletin 3849 illustrates and describes maker's "Conveyometer" self-testing feeder-weigher for stream delivery of small ground materials; covers specifications, applications.—Richardson Scale Co., Clifton, N. J.

S-274 PIPE DETECTOR. 4-page bulletin describes and illustrates maker's "Model 505" pipe detector; covers applications, features, specifications.—The Detectron Co., 5637 Cahuenga Blvd., No. Hollywood, Calif.

S-275 VERNIER CALIPER. 2-page bulletin describes and illustrates maker's vernier caliper; covers features, characteristics.—Vard Inc., 2981 E. Colorado Blvd., Pasendena 8, Calif.

S-276 GEIGER COUNTER. 2-page bulletin illustrates and describes maker's "Model DG-10" laboartory-type Geiger Counter (also lightweight "DG-2"); covers features, specifications.—The Detectron Co., 5637 Cahuenga Blvd., No. Hollywood, Calif.

S-277 HEIGHT GAGE. 2-page bulletin describes and illustrates maker's height gage; covers features, characteristics.—Vard Inc., 2981 E. Colorado Blvd., Pasadena 8, Calif.

S-278 INSIDE MICROMETERS. 4-page Bulletin R-3 describes and illustrates maker's inside micrometers; covers features, advantages; lists models, dimensions.—Rimat Machine Tool Co., 1117 Air Way, Glendale 1, Calif.

S-279 LIQUID-LINE FILTER. 4-page bulletin illustrates and describes maker's "Synclinal" filter for liquid line applications; covers uses, construction, dimensions, engineering data.—Marvel Engineering Co., 625 W. Jackson Blvd., Chicago 6, Ill.

S-280 ELECTRONIC COUNTER. 6-page Advance Bulletin describes and illustrates maker's "Model 410" industrial electronic counter; covers features, construction, applications; lists prices.—Berkeley Scientific Co., Richmond, Calif.

S-281 MAGNETIC MOUNTING DEVICE. 2-page Bulletin 39 describes and illustrates maker's "Miti-Mite" magnetic mounting device for test indicators, handi-lites, etc.; lists features, specifications.—Enco Mfg. Co., 4522-24 W. Fullerton Ave., Chicago 29, Ill.

S-282 "WET WATER" FOR FOUNDRY DUST CONTROL. 4-page bulletin illustrates and describes maker's "wet water" for dust control, product wetting, blending, mixing, washing.—Aquadyne Corp., 220 E. 42nd St., New York 17, N. Y.

S-283 CONTINUOUS BLOWDOWN SYSTEM, CHART. 4-page bulletin contains chart for determining proper size continuous blowdown system; gives complete instructions on use of chart, and system selection.—The Henszey Co., Watertown, Wis.

S-284 DIAL THERMOMETERS. 2-page bulletin illustrates and describes maker's dial thermometers and mounting accessories; lists specifications, prices.—Rochester Mfg. Co., Inc., Rochester 10, N. Y.

S-285 LATHES. 8-page Catalog L-10 illustrates and describes four models of maker's "Light Ten" lathe; covers specifications, prices; lists tools and attachments.—South Bend Lathe Works, South Bend 22, Ind.

S-286 "WHEELCO COMMENTS." 4-page Vol. 9, No. 2 issue of this house organ features articles on uses of maker's "Capacitrol," "Capacilog," and "Titrilog" recorders and controllers.—Wheelco Instruments Co., Harrison & Peoria Sts., Chicago 7, Ill.

S-287 WELDING CONTACTS. 6-page folder, Circular 501, illustrates and describes maker's "Steelback" contacts for welding; covers features and dimensions.—Gibson Electric Co., 8350 Frankstown Ave., Pittsburgh 21, Pa.

S-288 RADIOACTIVITY CATALOG. 90-page

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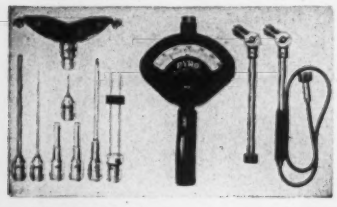

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S-289 RELAYS. 4-page bulletin illustrates and describes maker's circuit selectors and stepping relays; covers applications, features.—G. H. Leland Inc., 128 Webster St., Dayton 2, Ohio.

S-290 POTENTIAL DIVIDERS. 8-page bulletin describes and illustrates maker's "Types RV3-8 and RV3-2" potential dividers, accessories (dial plates, ganging parts), and "Constrict-O-Grip" instrument knobs; covers mechanical and electrical specifications, dimensions, features, impedance and phase angle characteristics, prices.—Technology Instrument Corp., Waltham 54, Mass.

S-291 MINIATURE BLOWERS. 2-page bulletin illustrates and describes maker's bantam blowers; list specifications, prices—Small Motors, Inc., 2076 Elston Ave., Chicago 14, Ill.

S-292 GEARED MOTORS. 2-page bulletin describes and illustrates maker's geared motors for applications from 1 rpm. to 200 rpm.; covers specifications, uses.—Small Motors, Inc., 2076 Elston Ave., Chicago 14, Ill.

S-293 MINIATURE DRILL PRESS. 4-page bulletin illustrates and describes maker's "Model 204-B" 6-inch drill press for small precision work; covers specifications, features, advantages.—Phillips & Hiss (formerly Cobb Precision Co., 6666 Lexington Ave., Hollywood 38, Calif.

S-294 ANALYTICAL BALANCE. 4-page bulletin describes and illustrates "Gram-atic" analytical balance (made in Switzerland); covers features, construction, operation; lists specifications.—Fisher Scientific Co., 717 Forbes St., Pittsburgh 19, Pa.

S-295 "CROSS CURRENT COMPENSATION." 4-page Bulletin C-201 discusses generator voltage regulator cross current compensation for parallel operation; contains wiring diagrams.—Burlington Instrument Co., Burlington, Iowa.

S-296 RADIOACTIVITY COUNTERS. Two 2-page bulletins describe and illustrate maker's portable survey and counter instruments; cover features and specifications of several models; lists prices.—Precision Radiation Instruments, Inc., Los Angeles 36, Calif.

S-297 PANEL INSTRUMENTS. 2-page bulletin describes and illustrates maker's panel instruments (milliammeters, microammeters, voltmeters, ammeters, and galvanometers); covers range, prices, specifications.—Cole Instrument Co., 1320 S. Grand Ave., Los Angeles 15, Calif.

S-298 GLASS PIPE AND FITTINGS. 4-page Catalog 94 illustrates and describes maker's glass pipe and fittings for laboratory, pilot plant and special services; covers advantages, dimensions; also metal-to-glass and glass-to-glass couplings.—Fischer & Porter Co., Hatboro, Pa.

S-299 GLASS SPECIALTIES. 8-page Catalog 95 describes and illustrates maker's "Glo-tech" precision-bore glass specialties; contains list of stock sizes in round, square and rectangular glass tubing.—Fischer & Porter Co., Hatboro, Pa.

S-300 INSTRUMENT CONTROL BOARDS. 8-page bulletin illustrates and describes maker's instrument control boards (duplex switchboards, benchboards, rectifier control cubicles); covers features, applications.—Allis-Chalmers Mfg. Co., 942 S. 70th St., Milwaukee, Wis.

S-301 "CENCO NEWS CHATS." 28-page No. 67, Spring 1950 issue of this house organ features article on Dr. Henry G. Knight, chemist; also article titled "Demonstrates Optics with Microwaves"; covers maker's various laboratory equipments.—Central Scientific Co., 1700 Irving Park Road, Chicago 13, Ill.

S-302 "C-D CAPACITOR." 16-page Vol. 15, No. 3 issue of this house organ features article on maker's ultra-high-resistance center-zero d-c. voltmeter; contains regular feature "The Radio Trading Post"—a free market-place for buyers, sellers, and swappers.—Cornell-Dubilier Electric Corp., Hamilton Blvd., South Plainfield, N. J.

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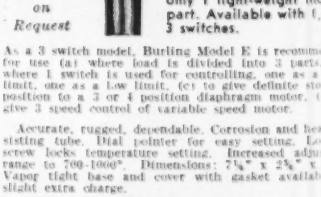

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S-304 TEMPERATURE AND HUMIDITY CONTROL. 32-page Catalog CD 50 describes maker's line of unit coolers, valves, automatic defrost systems, coils, etc.; covers complete specifications, performance data, engineering data; contains "quick selection" chart.—Tenney Engineering, Inc., 26 Avenue B, Newark 5, N. J.

S-305 VERNIER CALIPERS. 2-page bulletin illustrates and describes maker's "Tuna" (Swedish-made) precision Vernier calipers; covers specifications, price.—Swedish Gage Co. of America, 8900 Alpine, Detroit 4, Mich.

S-306 "ALLIED RADIO AND ELECTRONIC NEWS." 4-page Vol. 6, No. 1 features articles on maker's radio and electronic equipment; contains insert page on "el" xenon gas-filled tubes.—Allied Radio Corp., 833 W. Jackson Blvd., Chicago 7, Ill.

S-307 "THE LABORATORY." 24-page Vol. 19, No. 4 issue of this house organ features an article titled "Science Harnesses the Enzymes"; also contains articles on maker's isotemp oven, mixers, and other laboratory apparatus.—Fisher Scientific Co., 717 Forbes St., Pittsburgh 19, Pa.

S-308 "THE OHMITE NEWS." 2-page March issue of this house organ features articles on maker's rheostats, resistors, chokes, switches.—Ohmite Mfg. Co., 4835-41 Flournoy St., Chicago 44, Ill.

S-309 MACHINE TOOLS. 8-page bulletin "Machine Shop Time Savers" describes and illustrates maker's radii and angle dressers, cutting tools, vise jaws, parallels, jaw clamps; discusses form-grinding service; covers advantages, uses.—J. & S. Tool Co., Inc., 477 Main St., East Orange, N. J.

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S-311 "DUREZ PLASTICS NEWS." 8-page Vol. 17, No. 3 issue of this house organ features articles on maker's plastic materials (insulation coating; molded instrument cabinets, doors, etc.; molding compounds).—Durez Plastics & Chemicals, Inc., North Tonawanda, N. Y.

S-312 LABORATORY APPARTUS. 2-page bulletin with insert illustrates and describes maker's transparent plastic boxes, stainless steel weighing dishes, boiling stones, viscosity tubes, etc.; lists specifications, prices.—R. P. Cargille, 118 Liberty St., New York 6, N. Y.

S-313 ANNUNCIATORS. 4-page bulletin illustrates and describes maker's "Type ANG" annunciators for control panels, control desks, etc.; covers dimensions (from one to 400 windows), and applications.—The Autocall Co., 818 Tucker Ave., Shelby, Ohio.

S-314 THERMOSTATIC BIMETAL. 4-page Bulletin 1a-10 describes maker's thermostatic bimetal actuating elements for temperature responsive devices; covers properties, formulae, calculations, characteristics.—W. M. Chace Co., 1636 Beard Ave., Detroit 9, Mich.

S-315 FLARELESS FITTINGS. 6-page Bulletin 1-10 illustrates and describes maker's all-

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